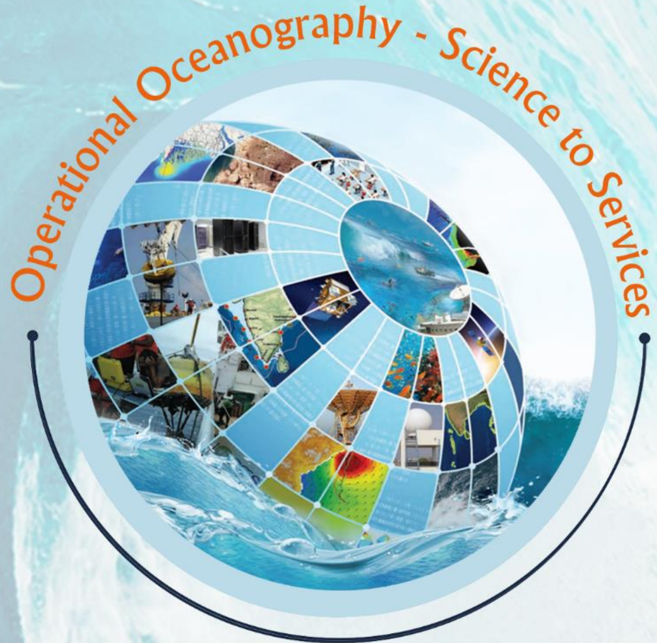
Eighth National Conference of Ocean Society of India



OSICON-23

August 23-25, 2023

ABSTRACTS

Hosted
by
Indian National Centre for Ocean Information Services (INCOIS)
(Ministry of Earth Sciences, Govt. of India)
Hyderabad

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Message

I'm pleased to warmly greet all participants of the 8th biennial Ocean Society of India Conference, OSICON-23, held at the Indian National Centre for Ocean Information Services (INCOIS, Hyderabad) from 23-25 August 2023. The resonance between OSICON-23's themes and the focal areas of the Ministry of Earth Sciences (MoES, Govt. of India) assures me that the conference will offer a comprehensive blueprint of potential operational applications in oceanography to boost Blue Economy and achieve the United Nations Sustainable Development Goals.

MoES recently launched the ambitious "Deep Ocean Mission (DOM)" project with six key objectives. This mission seeks to achieve sustainable development by unlocking the potential of our oceans for economic growth, environmental preservation, and strategic security. OSICON-23 is centred around the theme "Operational Oceanography - Science to Services," aligning perfectly with India's dedication and MoES pursuits to harnessing our oceans for sustainable progress.

Over time, our scientific pursuits have evolved from the quest for pure discovery to the application of scientific insights for the greater good of society. OSICON-23 embodies this transformation which harmoniously resonates with this evolved perspective. I firmly believe that OSICON-23 will witness a convergence of minds, including ocean-observing scientists, ocean modellers, policymakers, students, and academia. In doing so, it will stand as the best platform to deliberate upon the current state of operational oceanography and to identify the areas that require focused attention for enhancement and the delivery of improved services to our society.

Anticipating the impactful outcomes that will undoubtedly arise from this conference, I extend my sincerest best wishes to each participant of OSICON-23.

Warm regards,

Dr. M. Ravichandran
Secretary to Govt. of India,
Ministry of Earth Sciences

Message

I am immensely pleased that INCOIS is hosting the 8th biennial OSICON-23 conference on its campus from 23-25 August 2023. With its central theme, "Operational Oceanography – From Science to Services," the conference beautifully reflects the core mission of INCOIS, recognized globally as one of the leading operational oceanographic centres.

This edition of OSICON coincides with the Silver Jubilee year of INCOIS, signifying a quarter-century of invaluable service to our nation and positively impacting a substantial portion of our population. INCOIS stands uniquely as an integrated centre, seamlessly merging various branches of oceanography, marine meteorology, and environmental sciences to provide real-time data, advisories and forecasts for maritime safety, disaster mitigation, and resource management in a sustainable manner. Its focus on operational oceanography positions INCOIS as a global leader in harnessing oceanographic insights for practical applications and policy support.

It is expected that the OSICON-23 will have a participation of approximately 400 attendees from all over India. The delegates will deliberate on a wide range of topics in the operational oceanography across 14 distinct sub-themes. In this context, I hold a strong conviction that OSICON-23 will serve as a broad canvas for shaping the future trajectory of operational oceanography research in India. Anticipating enlightening talks on cutting-edge oceanographic facets and their applications, I am hopeful that OSICON-23 will also foster interactions between young scientists and field pioneers, thereby nurturing a cadre of young talent to uphold the torch of operational oceanography in the years ahead.

I wish all the attendees a very memorable and engaging time at INCOIS.

Dr. T. Srinivasa Kumar
Director, INCOIS &
Chairman, OC, OSICON-23

Message

The Ocean Society of India (OSI) is a professional society of ocean scientists and technologists of the country with a mission to provide a forum for sharing the knowledge and experience of individuals, research institutions and industrial organizations. OSI Conferences (OSICON), the biennial flagship conference of OSI conducted since 2009, have been quite successful in bringing together students and professionals working in ocean science, technology and allied fields.

OSICON-23 hosted by the Indian National Centre for Ocean Information Services (INCOIS) is the Eighth in the series. Dr. M. Ravichandran, Secretary, MoES who is the Patron and the National Advisory Committee with Dr. Shailesh Nayak, Director, NIAS and Former Secretary, MoES as Chairman have been the source of inspiration and guidance for the organisers. We at the OSI are overwhelmed by the unprecedented response that the conference received from students and professionals from across the length and breadth of the country. We have as many 508 abstracts received for the conference under the 11 themes enlisted. The Organising Committee with Dr. T. Srinivasa Kumar as Chairman and Shri Pattabhi Rama Rao as Convenor has done a wonderful job by taking care of the nitty-gritty of organising the conference. The Technical Committee has done a marvellous job by completing the review of the record number of abstracts received in a record time. The Conference is scheduled to have as many as 208 oral presentations, 58 flash talks and 77 poster presentations. The organisers have taken pains to schedule several plenary sessions which will be addressed by outstanding scientists from different field of ocean science and technology. The first ever Dr. N. K. Panikkar Memorial Lecture of OSI is scheduled to be delivered by Dr. Shailesh Nayak. The acceptability of OSICON among the scientific fraternity and societies is evident from the fact that the conference is scheduled to have special sessions sponsored by the FIGA and IMS. Honouring the professionally acclaimed and outstanding scientists with OSI Fellowships and Awards is going to be another important event. The budding researches of the country will be honoured with an exclusive session for their presentations and PG Dissertation awards. Another novelty of the Conference will be the ECOP Workshop for early career professionals.

I am quite confident that the OSICON-23 will be a big success. May the conference give each and every delegate the occasion to enrich their knowledge through deliberations and discussion. I welcome you all to OSICON-23 and look forward to your active and enthusiastic participation.

Dr. N. P. Kurian
President, OSI &
Former Director, NCESS

Preface

OSICON-23, the biennial national conference of the Ocean Society of India, will be hosted by Indian National Centre for Ocean Information Services (INCOIS), Ministry of Earth Sciences, Govt. of India, Hyderabad during 23-25 August 2023. The focal theme of the OSICON-23, the 8th edition of OSICON, is "Operational Oceanography - Science to Services". The call for papers received an overwhelming response from the oceanographic community spread across the country. After a thorough peer review process, 343 research papers, which related to at least one of the 14 sub-themes of the conference, are selected for presentation in OSICON-23. It is expected that the conference spread over 3 days in 6 parallel sessions will deliberate on the different facets of operational oceanography, including the ocean observations, climate change, ocean engineering and technology, ocean modelling and data assimilation, coastal ocean processes, air-sea interaction etc. and will come up with specific recommendations for the R&D in ocean sciences and technology to boost the contribution of the 'Blue Economy' to the total GDP of the country and thereby contributing towards achieving the United Nation's 'Sustainable Development Goals'. On behalf of the organisers of OSICON-2023, all are invited to attend the conference sessions and take part in the discussions to make the event a grand success. This abstract volume summarises the key findings of each presentation for the benefit of the readers.

Conference Proceedings Committee

18th August 2023

INCOIS, Hyderabad

OSICON-23 Program Committees

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OSICON-23 Programme Schedule

Time	Atal Bhavan (ITCOO) Hall-1 (Plenary Hall)	Atal Bhavan (ITCOO) Hall-2 (E-Classroom)	Atal Bhavan (ITCOO) Hall-3 (Breakout Room)	Main Building Hall-4 (Auditorium)	Main Building Hall-5 (E-class Room)	Main Building Hall-6 (Board Room)
23 August 2023 (Wednesday)						
1000-1100	**Registration**					
1100-1130	***Tea***					
1130-1300	**Inaugural Session**					
1300-1400	**Lunch & Inauguration of OSICON-23 Exhibition**					
1400-1545	Ocean Observations (In-situ & Satellite)	Ocean Information and Advisory Services	Ocean Engineering and Technology *(Will continue as Parallel Session during 1600-1745)*	Coastal and Open Ocean Processes	Biodiversity and Ecology	Blue Economy & Marine Resource Management
1545-1600	***Tea***					
1600-1745	**Plenary Session (Launch of UN Ocean Decade Collaborative Centre for Indian Ocean Region)**					
1800-1900	**Dr. N. K. Panikkar Memorial Lecture**					
1900-2000	**OSICON-23 Cultural Event - Beyond the Blue**					
2000-2100	**Dinner – Hosted by INCOIS & OSICON-23**					
24 August 2023 (Thursday)						
0930-1030	**Invited Plenary Talk**					
1030-1100	***Tea***					
1100-1300	Ocean Observations (In-situ & Satellite)	Ocean Information and Advisory Services	FIGA-Energy and Fresh Water from Oceans	Coastal and Open Ocean Processes	Biodiversity and Ecology	OSI- PG Dissertation Awardee Session
1300-1400	***Lunch***					
1400-1530	Ocean Observations (In-situ & Satellite)	Ocean and Climate Change	IMS-Importance of Ocean Observations to Monsoon Weather and Climate Forecasting	Coastal and Open Ocean Processes	Biodiversity and Ecology	Business Meetings
1530-1600	***Tea***					
1600-1800	Ocean Observations (In-situ & Satellite)	Ocean and Climate Change	IMS-Importance of Ocean Observations to Monsoon Weather and Climate Forecasting	Coastal and Open Ocean Processes	Polar Science and Cryosphere Studies & *Marine Geology and Geophysics*	ECOP Session/Workshop
1830-2100	**Invited Plenary Talk + Industry Talks + Dinner**					
25 August 2023 (Friday)						
0930-1030	**Invited Plenary Talk**					
1030-1100	***Tea***					
1100-1300	Ocean Modelling and Data Assimilation	Ocean and Climate Change	Air-Sea Interactions	Biogeochemistry of the Ocean	Polar Science and Cryosphere Studies & *Marine Geology and Geophysics*	
1300-1400	***Lunch***					
1400-1530	Ocean Modelling and Data Assimilation	Ocean and Climate Change	Air-Sea Interactions	Biogeochemistry of the Ocean	Polar Science and Cryosphere Studies & *Marine Geology and Geophysics*	
1530-1600	***Tea***					
1600-1730	**Valedictory Session (Panel Discussions + OSI PGDA Awards + Best Paper & Poster Awards, Closing Ceremony)**					

Note: Exhibition & Posters will be open for viewing during lunch/ tea breaks.

Sub-Theme-01

Ocean Information and Advisory Services

Reg. ID	Abstract Title	First Author
ABS-01-0046	Detection of Marine Debris Using high resolution satellite Imagery: A Promising Approach for the Effective Monitoring and Management for the Indian coast.	Jishad. M
ABS-01-0100	On the seasonal and inter-annual variability of Marine Heat Waves in the Indian Ocean	Prakash Chandra Mohanty
ABS-01-0165	Tsunami modelling over global oceans	Siva Srinivas Kolukula
ABS-01-0253	Climatology of Evaporation Duct and Marine Atmosphere Boundary Layer	Kameshwari Nunna
ABS-01-0400	Utilizing the oil concentration in tar sands to validate the simulated surface concentration of the spilled crude oil	Prasad SJ
ABS-01-0435	INCOIS Operational Forecast and Advisory Services for Science to Society: Planning, life saving and livelihoods (Ocean State Forecast (OSF) and Potential Fishing Zone (PFZ))	Rakhi
ABS-06-0336	Estimation of nutrient flux using LOICZ model: A case study of the Mahanadi estuary	Susmita Raulo
ABS-01-0397	Comparative Study on the Utilization of SST Data from Geostationary INSAT 3D & 3DR for operational fishery advisory services	Nagaraja Kumar Masuluri
ABS-01-0391	Spatio-temporal variability of oceanic conditions during the Extremely Severe Cyclone Storm ¿Mocha¿ in the Bay of Bengal	Ajay Kumar Bandela
ABS-01-0194	Enhancement of wind and pressure fields from a global model and their application in storm surge and wave computations: A case study using ERA5 winds.	Murty P L N
ABS-01-0454	Studies on oceanographic and marine met features and processes in the Indian Ocean for Industry-demanded ocean consultancy projects/services: an evidenced blue economy growth perspective	Harikumar R
ABS-01-0402	Seasonal and interannual variability of wave conditions at the Central Indian Ocean Basin (CIOB) mining site (13.5 °S, 75.5 °E) of India	Srinivas K
ABS-01-0178	Development of oil spill response strategies using INCOIS Operational oil spill advisory services	Prasad SJ
ABS-01-0240	Evaluation of wind forecasts from the operational Advance Research WRF using Buoys in the Indian Ocean	Anuradha Modi
ABS-01-0358	Ocean Data services through heterogeneous dissemination modes	Udaya Bhaskar TVS
ABS-01-0305	Creation of a WebGIS Application for Ocean Information and Advisory Services using effective Open-Source Software	Kiran Kumar N
ABS-01-0490	INCOIS's Operational Advisory, Forecast and Early Warning Services	Sivaiah Borra
ABS-01-0437	Training and Capacity Development: Keystone for Sustainable Operational Ocean Information and Advisory Services	Nimit Kumar
ABS-01-0408	Ocean Data Analytics as a Service for effective decision-making	Pavan Kumar Jonnakuti
ABS-01-0196	A multidecadal study of the Malabar Upwelling System influencing Indian Mackerel catch along the coasts of Karnataka and Kerala, south-east Arabian Sea	Sneha Jha
ABS-01-0370	Inherent Optical Properties (IOP) of phytoplankton bloom in northern Arabian Sea during winter season using EOS-6/Ocean Colour Monitor-3 and Sentinel-3/OLCI	Arvind Sahay
ABS-01-0486	Accident Causation Models for Capture Fisheries Research: A Comprehensive Review using Haddon Matrix	Sabu Maria

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ABS-01-0327	Evolution and recent trends of Indian oil Sardine research- Indian context	Bhagyashree Dash
ABS-01-0388	Detection and Analysis of Ionospheric Signature of Turkey Earthquake	Vishnu K Nambiar
ABS-06-0337	Investigating Indian Oil Sardine run event in coastal waters of the southeastern Arabian Sea	Sanjiba Kumar Baliarsingh
ABS-07-0301	Unveiling the Connection: How Cyclone Mocha Influence Jellyfish Stranding on Puri Beach of Odisha	Sathish Chennuri

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Detection of Marine Debris Using high resolution satellite Imagery: A promising approach for the effective monitoring and management for the Indian coast.

[ABS-01-0046]

Jishad M*, Devanshi Kotecha, Surisetty VV Arun Kumar, Rashmi Sharma, Neeraj Agarwal
Space Applications Centre-ISRO

Marine debris (MD) are a global environmental issue with harmful effects on marine ecosystems. To effectively manage and mitigate this problem and create a better living environment, it is crucial to detect and monitor MD. Remote sensing has emerged as a promising method for detecting marine debris by making use of high resolution Earth Observation satellites with Multispectral instrument. In this study an attempt has been made to delineate the signatures of marine debris in the satellite observations from other effects. To this end, an image processing technique was developed to identify marine debris from satellite images using various spectral bands of Sentinel-2. The detection of floating materials on subpixel scales relied on two key indexes: the Floating Debris Index (FDI) and the normalized difference vegetation index (NDVI). Spectral signatures were used to identify the dominant materials within pixels on the ocean surface from space. The reflectance intensity was primarily determined by the proportion of floating plastic within the pixels. Once \the pixels containing floating debris were identified, an un-mixing algorithm was employed to filter out noise pixels. The technique was applied to Sentinel-2 data for the period 2021-2022 for various Indian coasts (Goa, Mumbai, Chennai, Kochi and Gujarat). At Mumbai and Chennai coasts a clear time variation of MD was observed during the study period, while no definite signatures were found along the Gujarat coast in the dataset. This approach has the potential to become a valuable tool in the fight against marine debris, aiding in the efforts to clean up our oceans.

Keywords: Marine Debris, FDI, NDVI, unmixing

On the seasonal and inter-annual variability of marine heat waves in the Indian Ocean

[ABS-01-0100]

Mohanty P C*, R S Mahendra, N Kiran Kumar, R K Nayak, Sudheer Joseph, Balakrishnan Nair, T. Srinivasa Kumar
Indian National Centre for Ocean Information Services

The Marine Heat Wave (MHW) is a prolonged extreme warming of ocean surface water above 90 percentile of local climatology, which persists for five days or more. In the last decade, the frequency of MHW events have been increased, which have resulted in adverse impacts on Marine ecosystems. The present study has been conducted to assess the trend and the seasonal and inter-annual variability of MHWs using Optimum Interpolation Sea surface temperature (OISST) data acquired from 1982 to 2023. The results showed that basin-wide high intensity MHWs were associated with climate modes such as ENSO and IODM in the Indian Ocean. An empirical relationship between the intensity of MHWs and coral bleaching percentage has been established. A declining ocean productivity and fish catch were are also observed due to the increasing frequency of MHW events. The lag/lead relationship between MHW with different parameters such as solar insulation, heat fluxes, cloud cover, wind, mixed layer heat budget and horizontal advection was established to understand the intensity changes during the onset and declining phases of MHWs. The INCOIS issues daily MHW advisory as a service that can benefit and provide guidance to marine ecological conservation, fisheries, aquaculture management and other stockholders.

Keywords: Climatology, ecosystem, Heat flux, Mixed Layer Depth, ENSO

Tsunami modelling over global oceans

[ABS-01-0165]

Siva Srinivas Kolukula*, P L N Murty
Indian National Centre for Ocean Information Services

In the aftermath of the 2004 Indian Ocean tsunami, a significant increase in tsunami hazard and risk mapping activity is observed. Predicting real-time tsunami wave heights and the resulting coastal inundation is crucial for protecting the lives and properties of coastal communities. Most of these are site-specific studies with detailed modelling of the run-up locally. However, fewer studies exist on the regional and global scale. This study focuses on tsunami simulations over global oceans. A widely used finite-element-based ADvanced CIRCulation (ADCIRC) model for storm surge simulations is configured to the global domain. The model mesh has a spatial resolution of 2km in the shallow waters and relaxed to 20 km in the deeper waters. Model simulations are performed for the four historical events, and their effect on global oceans and their origin area is assessed. The computed results are compared with the available observations, and it is found that the model's predictions align well with the actual data. The simulation results demonstrate that ADCIRC can be applied to near real-time prediction at tsunami warning centres due to its computational efficiency and accuracy. Furthermore, this study suggests the configuration of ADCIRC in real-time in tsunami warning centres for global oceans.

Keywords: Tsunami, modelling, ADCIRC, wave height, warnings

Climatology of evaporation duct and marine atmosphere boundary layer

[ABS-01-0253]

Kameshwari Nunna*, TVS Udayabhaskar, Pattabhi Rama Rao E, Osuri Krishna Kishore
Indian National Centre for Ocean Information Services

Evaporation duct height forms due to change in refractive index of the atmospheric boundary layer air. The humidity of the atmospheric surface layer governs the profile of the refractive index of the air. Due to the changes in the refractive index, a trapping layer forms, which is referred as an Evaporation duct. The presence of this layer is very crucial for radio wave communications. The marine meteorological observations from ships are used to build a climatology to describe the characteristics of the Evaporation duct in the North Indian Ocean Region. Annual climatology, monthly climatology, and individual year-month summaries of Evaporation duct height are generated and their distinguished characteristics are discussed. The dependance of Evaporation Duct Height on other atmospheric surface layer parameters is also discussed.

Keywords: Indian Ocean, Atmosphere Boundary Layer, Evaporation Duct, Climatology

Utilizing the oil concentration in tar sands to validate the simulated surface concentration of the spilled crude oil

[ABS-01-0400]

Prasad S J*, Trinadh Rao, Sudheer Joseph, T.M.Balakrishnan Nair, T.Srininasa Kumar
Indian National Centre for Ocean Information Services

Crude oil transferred through a 9km long, 20inch carbon steel pipeline, between the oil wells and a port. It got cracked at Nagore beach (79.850923 °E, 10.821029 °N). On 02 Mar 2023 night, the local fishers noticed an oil leak. The spilled crude oil reached the shore on the same day, as the cracked pipeline was at the shore. Later it was noticed to spread southward along the coast. Oil drift patterns were generated to advise the coastal community on further spread of the pollutant. As per the simulations, it was noticed that the pollutant will spread further south during the next days. According to the simulation, 10.33 Km of coastline would have been affected due to this crude oil leak by 05 of March 2023. The simulated particle density was found high at Samanthapettai and Nambiar Nagar coasts the same day. Satellite datasets (Sentinel -1, 2) were obtained from ESA and processed using SNAP tool. Oil slick signatures were not identified in those datasets. In connection with this, a field survey was conducted during 10-11.03.2023 to examine the spread of the spilled crude oil along the shoreline from the source location. The soil samples (tar sands) were collected at five locations and were subjected to gravimetric analysis to estimate the oil content. As per the analysis, oil content was reported at all five locations, but a higher concentration of 1445 mg/Kg was found at Nambiar Nagar, which is ~ 4.5 Km from the source (spill) location. Even though the shore was found clean during the survey, oil remnants in the soil samples were found through the lab analysis even after eight days of spill. The forecasted locations of the beached particles agree with the surveyed and sampled locations, however on 05.03.2023, an overestimation of 2.5 Km was found from the simulation, which is to the south of Keechankuppam. In this paper, the method of simulating oil spill trajectories using a Lagrangian model and validating the simulated drift patterns using the field information are addressed.

Keywords: Tar sands, oil spill, crude oil, pipeline, concentration

INCOIS operational forecast and advisory services for science to society: Planning, life saving and livelihoods (Ocean State Forecast (OSF) and Potential Fishing Zone (PFZ))

[ABS-01-0435]

Rakhi*
Indian National Centre for Ocean Information Services

The Indian National Centre for Ocean Information Services (INCOIS) is the Indian nodal agency to provide operational Ocean State Forecast (OSF) and Potential Fishing Zone (PFZ) advisory services to various government and industrial users, including offshore industries, the coastal population, fishermen, navy, coastguard, port and harbors, maritime boards etc. We provide daily updated user-customised forecasts from ECMWF and NCMRWF data sources from various models to provide output for various parameters of wave height, direction and period (of wind waves and swells), Sea surface currents, SST,MLD,D20, Astronomical tides, Wind speed and direction and Oil-spill trajectory, Search and Rescue Aid Tool (SARAT), Small Vessel Advisory Services etc. Modern trends of Information and Communication Technology are used right from the forecast generation, evaluation & fine-tuning until the forecast dissemination to the end users. The dissemination modes include Email, Website,Telephone, Radio, TV, Social media and Mobile phones(SMS), NAVIC, GAGAN; individually or in combination. Apart from daily operations during extreme weather conditions, Joint INCOIS-IMD bulletins consisting of the meteorological and oceanic information and forecasts, along with separate high sea state warnings, are issued. Data assimilation with various satellites and observation satellites is being used in ocean model forecasts using real-time observations from different parts of the Indian ocean for accurate forecasting for marine operations. The Potential Fishing Zone (PFZ) uses vital parameters such as Sea Surface Temperature and Chlorophyll from sources like NOAA-AVHRR, MODIS, OCM, VIIRS-NPP, GHRSST. A reliable and timely advisory on the potential zones of fish aggregation benefits the fishing community to reduce the time and effort spent in searching the shoals of fish, thus improving the profitability

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and hence, the socio-economic status. User feedback and delayed mode evaluation/auditing suggest not only that the forecasts are > 80% accurate, but also that the forecasts/information reach the maximum end users on time, which is also equally crucial for saving life and property.

Keywords: INCOIS, OSF, PFZ

Estimation of nutrient flux using LOICZ model: A case study of the Mahanadi estuary

[ABS-06-0336]

Susmita Raulo*, Sanjiba Kumar Baliarsingh, Alakes Samanta, Aneesh A. Lotliker, Tamoghna Acharyya, Sudheer Joseph, Balakrishnan Nair, T.M
Indian National Centre for Ocean Information Services

The present study addresses inorganic macronutrient flux in a river-sea continuum of the Mahanadi and the western Bay of Bengal. Spatial variability of different physico-chemical parameters, viz. salinity, temperature, and nutrients, were investigated over a tidal cycle during February 2021 (post-southwest monsoon and low flow period). The nutrient budget was estimated using LOICZ (Land-Ocean Interactions in the Coastal Zone) model with the spatial data from the stations of upstream, estuary, and nearshore waters for a better understanding of the nutrient pathways, health, and functioning of the ecosystem. The biogeochemical mass balance simple box and layer model was used to estimate the water, salinity, and nutrient flux between upstream-downstream-adjacent coastal water. The results revealed very low (<1 day) residence time of water mass, both at upstream and downstream. The residence time also varied with the tidal cycle, which was relatively higher during low tide and lower during high tide. The nutrient budget revealed upstream as the major source of the nutrients (mostly DIP), probably sourced from the industrial effluent discharge. The +ve ΔDIN and ΔDIP represented the upstream as a source, whereas +ve ΔDIN and ΔDIP represented the downstream as a sink. The net ecosystem metabolism (NEM) was mostly positive at downstream, which implies the autotrophic condition of the ecosystem. On the contrary, the NEM was negative at upstream, representing the system as heterotrophic. The evaluation from the LOICZ model highlighted that nitrogen fixation prevailed over the denitrification at downstream due to the high metabolic activity and lower nitrogen fixation values than the denitrification at upstream due to the less metabolic activity. The overall result represented a healthy estuarine condition. The autotrophic condition in downstream of the estuary signified efficient utilization of nutrients resulting in relatively less probability of eutrophication in the coastal waters.

Keywords: Salinity, Mahanadi, Bay of Bengal, Flux, LOICZ

Comparative study on the utilization of SST Data from Geostationary INSAT 3D & 3DR for operational fishery advisory services

[ABS-01-0397]

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Cloud cover has been one of the major hindrances to operationally issue Potential Fishing Zone (PFZ) Advisories at Indian National Centre for Ocean Information Services (INCOIS). Several studies have been carried out in the past by INCOIS for studying feasibility of utilization of various other data sources such as optimally interpolated datasets i.e., GHRSST, etc., however the cloud limitation remains an issue since due to their presence the gradient information in the optimally interpolated products is lost. To address this issue, we explored the use of geostationary satellite INSAT 3D & 3DR Sea Surface Temperature (SST) (Geo-SST) for operational services. The present study focusses on feasibility of using the data for identification of thermal Frontal structures within Indias Exclusive Economic Zone (EEZ) region. The study was carried out as a comparative exercise to find out whether identified gradients in Geo-SST data are comparable with the SST derived from other Polar orbiting NOAA series of satellites (Polar-SST) and statistical significance of the math. SST data for the year of 2022 was analyzed in Geographic Information System (GIS). It was observed that a strong gradients / features were identified by INSAT satellites and well-matched with Polar-SST. Whereas, identifying Gradients in INSAT 3D & 3DR in the near coast region is complex. We infer that while standalone utility of Geo-SST data may vary it is one of the best tool at present to fill the data gaps in Polar-SST products for identification of Thermal Gradients/ Fronts/ Features to generate the Potential Fishing Zone (PFZ) Advisory for Pelagic Fisheries. Another advantage with Geo-SST product is the possibility of providing fishery advisories multiple times in a day.

Keywords: Geostationary, Sea Surface Temperature, PFZ, INSAT 3D, INSAT 3DR

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Spatio-temporal variability of oceanic conditions during the extremely severe cyclone storm mocha in the Bay of Bengal

[ABS-01-0391]

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The spatio-temporal variability of oceanic conditions during the Extremely Severe Cyclonic Storm (ESCS) ¿Mocha¿ during the period 09-14 May 2023 was studied using models and observations. Mocha cyclone experienced peak winds (280 kmph) on 14 May similar to that in Fani Cyclone (Apr-May, 2019), the strongest storm on record in the north Indian Ocean, in terms of one-minute sustained winds. Indian National Centre for Ocean Information Services (INCOIS) issued thirty-three (33) Joint Bulletins along with Indian Meteorological Department (IMD) on Ocean State Forecasts (OSF) and alerts/warnings during Mocha cyclone. Validated the ocean forecasted models with observational platforms. The ESCS Mocha cyclone tracked northwards through the Central Bay of Bengal and coastal wave signatures were less (Wave Rider Buoys located at Gopalpur, Vizag and Krishnapatnam) as compared to the deep-sea signatures. The data assimilated WAVEWATCH III (WW3) model forced by European Centre for Medium-Range Weather Forecasts (ECMWF) winds showed the best forecast followed by the WW3 model without Data Assimilation forced by ECMWF winds. This conclusion is based on the high correlation coefficient, minimum bias, low RMSE, and the low Scatter Index (less than 30%), as evident in the statistics. Further, BD08, BD09, BD10 and BD13 buoys were located in proximity to the path of the cyclone and would have experienced higher Significant Wave Height (SWH) as suggested by the wave model outputs. The system was tracked throughout and INCOIS actively warned the multitude of users on the coastal as well as deep sea oceanic conditions associated with the Mocha cyclone through multiple dissemination modes. The ESCS Mocha made landfall at Myanmar near the Sittwe coast with a maximum sustained wind speed of 180-190 kmph gusting to 210 kmph during afternoon hours of 14th May 2023. INCOIS forecasted the maximum peak storm surge of 4.4 m over and above the astronomical tide along the Myanmar coast for the Mocha cyclone.

Keywords: Cyclone, Ocean State Forecast, Numerical Models, Obs. Platforms

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Enhancement of wind and pressure fields from a global model and their application in storm surge and wave computations: A case study using ERA5 winds.

[ABS-01-0194]

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In this article, we focused on enhancing the accuracy of ERA5 wind and pressure fields specifically during cyclonic events. To achieve this, we utilized best track data, which is a reliable record that provides the most precise information regarding a tropical cyclone's center, size, and intensity. By incorporating this data, we were able to improve the ERA5 dataset and subsequently simulate storm surge and significant wave heights during recent cyclone events. A remarkable increase in peak surge heights, with a staggering about two-fold surge height augmentation is noticed using improved winds. Furthermore, the inundation area, which represents the extent of coastal flooding, also exhibited a substantial increase due to the improved data. Similar improvement has been noticed in peak significant wave heights experienced during cyclonic events. The enhanced wind and pressure fields play a crucial role in capturing the true amplitude of cyclonic waves, enabling a more comprehensive understanding of the potential threats posed by these events. Overall, our findings hold promising implications for the improvement of global early-warning systems and coastal flood hazard assessments. By incorporating the reconstructed ERA5 wind and pressure fields, we can enhance the accuracy and reliability of these systems, providing timely and precise information to communities at risk. This research marks a significant step towards bolstering the effectiveness of early-warning systems and reducing the vulnerability of coastal areas to cyclone induced storm surges and significant wave heights. Furthermore, the thorough validation conducted on these improved re-analysis fields resulted in the creation of a comprehensive database. This database contains the improved wind and pressure fields associated with cyclonic events dating back to 1990, offering a valuable resource for future studies and investigations in the field of meteorology and climate science. The availability of this dataset will facilitate further research and enable a deeper understanding of the dynamics and behaviour of cyclonic events over the past decades.

Keywords: Tropical Cyclone, Storm Surge, Inundation, SWH, ADCIRC+SWAN

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Studies on oceanographic and marine met features and processes in the Indian Ocean for Industry-demanded ocean consultancy projects/services: an evidenced blue economy growth perspective

[ABS-01-0454]

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To tap the blue economy efficiently and sustainably by any industry, deep understanding about the characteristics of the ocean state in various perspectives-climatological, physical processes, nowcasting and forecasting- is of paramount importance. Indian National Centre for Ocean Information Services (INCOIS) is a world-renowned institution for operational oceanography and the only institution of its kind in the Indian Ocean region to provide operational ocean information, forecast, early warnings and advisory services over two decades. Offshore industries, shipping industry, port & harbours and maritime boards, in a commercial manner, also are its constant users/clients for last a decade, apart from any other sea farers and coastal population. All these firms also avail oil-spill trajectory predictions, search and rescue aid tool, forecast along ship-routes, sea state forecast for port and harbours etc. The assessment of wind potential in the western offshore field of ONGC was carried out and supplied. Projects on Inland Vessel Limits (IVL) zonation and demarcation and its dynamic versions were done for gazette purpose of five different port authorities and maritime administrations for different seasons, which in turn, helps them in enhancing their economy/business through safe port operations in the context of 'Sagar Mala' project of Ministry of Shipping. Specialised location-specific daily operational forecasts have been issued to M/S ONGC and M/S AFCONS. Ocean-met desktop studies on return period, extreme value analysis, coastal and offshore platform design parameters etc in connection with marine met parameters were done for ONGC. Studies on design parameters based on wave, swell, wind and on hypothetical oil-spill trajectory prediction were also executed for Jawaharlal Nehru Port Trust (JNPT). A project is underway for Adani Vizhinjam port for providing them consultancy on

oceanic conditions by establishing observational platforms. Clients list includes well known marine companies/clients such as L&T, Fugro, Ocean Sparkle, COWI India PVT Ltd. Periodic industry meets/workshops are conducted to fetch further user-requirements, and also to survey and collect the feedbacks on our consultancies to better refining and further developing and expanding the offshore industry-specific projects from INCOIS. Scientific aspects of such projects would be presented and discussed.

Keywords: oceanographic, marine-met, ocean consultancy projects, user-demanded ocean products, blue economy

Seasonal and interannual variability of wave conditions at the Central Indian Ocean Basin (CIOB) mining site (13.5 °S, 75.5 °E) of India

[ABS-01-0402]

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The seasonal and interannual variability of the wind and associated wave conditions for the Central Indian Ocean mining site is analysed using numerical models for the period 2018-2022. The region experiences intense cyclones and identifying time windows for smooth operations at the location, taking the seasonal characteristics into consideration is of utmost importance. The data on winds and waves show clear seasonal variation over the 5-year period. The characteristics of the wind sea waves, and swell waves suggest an overall dominance of the wind sea waves over the swell waves. The wind speeds and associated waves are high during the months of June-August (Austral Winter). The wind speeds and the Significant Wave Heights during this period can go up to 15 m/s and 6 m, respectively. The peak wave period, the wave period associated with the most energetic waves in the total spectrum at the point are mostly concentrated between 10-16s. These simulations in the hindcast/forecast mode would be of paramount importance for the structural designing of the deep-sea mining ships as these vessels would be different from the regular ore carriers/FPSOs as well as for the smooth day to day operations at the location.

Keywords: Deep Sea Mining, CIOB, Wind Speeds, Significant Wave Heights

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Development of oil spill response strategies using INCOIS Operational oil spill advisory services

[ABS-01-0178]

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Indian National Centre for Ocean Information Services (INCOIS) has been involved in issuing oil spill advisories since 2011. Oil spill advisories issued by INCOIS to the Indian Coast Guard enhance preparedness, response efficiency, and coordination during oil spill incidents. They enable the Coast Guard to respond swiftly, allocate resources effectively, and mitigate the impacts of oil spills on the marine environment and coastal communities. In addition to the oil spill advisories, INCOIS started generating Oil Spill Response Strategy (OSRS) maps that contain the details of oil spill and plans to reduce injury to sensitive natural, cultural, and economic resources. They also set priorities for various spill risks and direct the response until real-time information becomes available. The present paper describes the method of generating OSRS maps for a hypothetical oil spill that occurred off the coast of Gujarat during July2023. The proposed oil spill response strategies were indicated in Geographical Information System platform which is collectively called as an OSRS map. The map contains information such as oil trajectory patterns, geomorphological classes, movement plan of oil spill response/Pollution control vessels, indication of shore-based facilities near to the spill location. This OSRS map will be communicated to the Regional and District Response Centers established by Indian Coast Guard wherein the centers serve as operational hubs for oil spill response activities in their respective regions. OSRS maps contribute to the incident command structure and decision-making processes of the Indian Coast Guard. The OSRS map along with oil spill advisories provide critical input to incident commanders, enabling them to assess the situation accurately, monitor the spill's progression, and make informed decisions regarding response strategies, resource allocation, and operational priorities. However, the availability of accurate and real-time information enhances the overall effectiveness of incident management.

Keywords: OOSA, oil spill response, strategies, maps, geomorphology

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Evaluation of wind forecasts from the operational advance research WRF using buoys in the Indian Ocean

[ABS-01-0240]

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The paper presents the evaluation of surface wind forecasts by a high-resolution-mesoscale atmospheric numerical model Advanced Research WRF (ARW3.7), which was set up to force the operational ocean models of the ocean state forecasting system at the Indian National Centre for Ocean Information Services (INCOIS). Evaluation is carried out by comparing the WRF first day wind forecasts with the Ocean Moored buoy Network for Northern Indian (OMNI) buoys for the year 2016 over the Indian Ocean. The evaluation was done separately for coastal (near-shore) and for open ocean (offshore) regimes considering the understanding from the literature that the coastal wind simulations are marginally poor than that pertaining to the open ocean regimes. The comparison of WRF forecasted winds against winds from offshore OMNI buoy with about 7953 match-up points indicated that the mean differences for wind speed and wind direction are -0.1 m/s and ?4.4°, the RMSEs are 2.1 m/s and 31.0° and the correlation are 0.75 and 0.51 respectively. For the coastal OMNI buoy winds having about 5896 match-up points, indicated that the mean differences for wind speed and wind direction are 0.6 m/s and 4.1°, the RMSEs are 2.2 m/s and 45° and the correlation are 0.63 and 0.65 respectively. The results suggest that the WRF model could predict the surface wind fields fairly realistic over the Indian region. The model also predicted the diurnal variability of the surface winds with reasonable accuracy. The capability of WRF forecasted winds during a cyclonic storm Vardah during December 2016 also is dicted. During cyclone Vardah (6-13, Dec 2016), the comparison of WRF forecasted winds with CB06 (80.32 E, 13.10 N) winds, indicated with the mean differences for wind speed and wind direction are -0.29 m/s and -3.8°, the RMSEs are 1.37 m/s and 46° and the correlation are 0.94 and 0.79 respectively. In the coastal regions, the high resolution WRF could pick the reality well

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compared to other global models. In a nutshell, these results gave required confidence to use WRF forecasted winds for forcing high-resolution global/regional ocean models for operational ocean forecasting at INCOIS.

Keywords: WRF, winds, INCOIS, OMNI buoys, diurnal variability

Ocean Data services through heterogeneous dissemination modes

[ABS-01-0358]

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The Indian National Centre for Ocean Information Services (INCOIS) is the central repository for heterogeneous data from in situ, remote sensing and ocean models pertaining to Indian Ocean. In-situ ocean observations from Argo floats, moored buoys, XBT/XCTDs, AWS, WRB, ADCP, Process Specific Cruises; Remote Sensing data from NOAA satellite series, OceanScat, Ocean Color etc and model outputs from ROMS, MOM, HyCOM etc are all archived. Data generated is translated into ocean information services through analysis and modelling. Data services is one of the many services that INCOIS renders to various stake holders. Under the data services, INCOIS pledges to provide data which is directly measured by instruments, processed data which is value added, data generated through operational services like PFZ, OSF, HABS, Coral bleach Alerts etc. Based on the type of the data, INCOIS uses different dissemination mechanisms to service the data to various stakeholders. This includes Digital Ocean a one stop shop for heterogeneous data sets; Web-services with GIS features, Live Access Server (LAS), ERDDAP with facilities to search, visualize and download. Users are provided the power to check for availability of all the data pertaining to the parameter of one's choice and visualize them and download them. All these dissemination mechanisms enable users to have unlimited access to all data that can be shared as per the National Data Sharing and Accessibility Policy of Govt. of India. Those data which are large in size will be shared through FTP and offline products using DVDs are also developed for ease of data distribution with those who have limited bandwidth for accessing the data.

Keywords: Data dissemination, Digital Ocean, LAS,ERDDAP,Web-based Services

Creation of a WebGIS application for ocean information and advisory services using effective open-source software

[ABS-01-0305]

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Geospatial technology is a vital platform for the generation, editing, analysis, visualization, and sharing of large amounts of spatial data providing a vital opportunity for decision-making and planning purposes. The augmentation of advanced ICT tools with the latest geospatial technology will enhance the capability of catering geospatial information to users more effectively. Openly available THREDDS Data Server (TDS) is a web application integrated with Apache Tomcat web server that maintains metadata and caters to scientific datasets using a variety of remote data access protocols such as OPeNDAP, OGC WCS, WMS, and HTTP. This web server supports a host of data services, including robust dataset aggregation capabilities. This facilitates the TDS to aggregate a collection of datasets into a single virtual dataset to simplify user access to that data collection. Time series data is stored in MySQL as an object-oriented relational database management system (ORDBMS). As a tool for effective dissemination and management of information over the Internet, ORDBMS has proved to be timely and cost-effective. Web-based Geographic Information System (WebGIS) can be used for displaying spatial information and can be accessed by any user over the internet. A graphical user interface is needed for this kind of application so that it is suitable for the user to look over the place of interest with a single mouse click. These free open-source software and servers can be effectively used in WebGIS technology. In this paper, we demonstrate the versatility of these technologies in ocean information and advisory services generated by Indian National Centre for Ocean Information Services (INCOIS) for the entire Indian Ocean utilizing GIS and Remote Sensing techniques and displaying the results through a WebGIS platform.

Keywords: WebGIS, ORDBMS, HTML, Disaster Management, Advisories

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INCOIS's operational advisory, forecast and early warning services

[ABS-01-0490]

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Operational oceanography encompasses the systematic and routine collection of oceanic and atmospheric measurements, followed by their prompt interpretation and widespread dissemination. Nowcast, forecast, and hindcast are essential products derived from operational oceanography. Operational oceanography swiftly transmits observational data to data assimilation centers, where powerful computers utilize numerical forecasting models to process the data and generate alerts, warnings, and other data products, which are then rapidly distributed to industrial users, government agencies, and regulatory authorities. Indian National Centre for Ocean Information Services (INCOIS) serves as the nodal agency in India for operational provision of advisory, forecast and early warning ocean services. The present study discusses the structure, operational functionality and significance of various operational ocean advisory, forecast and early warning services, such as Potential Fishing Zone (PFZ), Tuna Fishing Advisory (TFA), Ocean State Forecast (OSF), Small Vessel Advisory Services (SVAS), Oil Spill Advisories (OSA), Marine-Search and Rescue Aided Tool (SARAT), Indian Tsunami Early Warning Centre (ITEWC), Storm Surge Early Warning Services (SEWS), Coral Bleaching Alert Services (CBAS), Algal Bloom Information Services (ABIS), and Marine Heat Wave Advisory Services (MHAS). INCOIS functions as the Tsunami Service Provider (TSP) for 25 Indian Ocean countries, while also extending its OSF services to 6 neighboring RIMES countries, offering customized forecasts for ship routes, forts, harbors, and location-specific forecasts primarily for ONGC, Indian Navy, Coast Guard, Maritime Boards, etc., based on user requirements. This study highlights the significance of all operational ocean services being provided by INCOIS by examining the statistical analysis of the services offered to diverse users on a daily basis and during extreme events such as tsunamis, cyclones, storm surges, high waves, swells, perigean spring tides and more. In conclusion, this study provides a comprehensive overview of the importance and indispensability of INCOIS operational ocean services in meeting the needs of various users engaged in coastal and open ocean activities, including the fishing community, navigators, maritime and offshore industries, port and harbors, Indian navy and coast guard, disaster management authorities, coastal population, ecologists, environmentalists, and researchers

Keywords: INCOIS, OSF, ITEWC, PFZ, CBAS

Training and capacity development: Keystone for sustainable operational ocean information and advisory services

[ABS-01-0437]

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Globally, underdeveloped and emerging economies depend on the ocean resources for the livelihoods of the populations amounting to millions. This is because these countries either have an expansive or stationary population pyramid profile, with limited land resources. Their nutritional and employment needs will have more reliance on the Indian Ocean in the coming decades. Marine ecosystems are a promising source for the nourishment of populations and, at the same time, are under more serious threats than ever before. As more people are uplifted from poverty, consumerism is poised to extend to larger parts of the population, which will create concerns for the health of the adjoining ocean ecosystems. Operational ocean information services cater to the requirements of managers and end-users to efficiently harness those resources and to ensure safety. In this context, sustained operational ocean services will also require sustained training and capacity development efforts to ensure that skills are effectively transpired while maintaining geographical, gender and generational (3G) balance. Herein, we share the journey and experience of the International Training Centre for Operational Oceanography (ITCOOcean, a Category-2 Centre under IOC-UNESCO) in executing this mission. Since established in 2013, ITCOOcean has trained a total of about 5700 trainees from 96 countries through 85 programmes covering topics ranging from ocean observations, data and products management, application development to name a few. We will highlight how these trainings have helped in creating better operational service ecosystem in past two decades.

Keywords: Capacity Development, Training, Operational, Ocean, Services, International

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Ocean data analytics as a service for effective decision-making

[ABS-01-0408]

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Ocean data analytics as a service (ODAaaS) is crucial in informing policy and decisions in various domains, such as marine resource management, environmental protection, and maritime operations. By leveraging the power of business analytics-based dashboards, organizations can effectively analyze and visualize vast amounts of oceanic data to extract actionable insights and drive informed decision-making, presents the concept of ocean data analytics as a service, and highlights its significance in the context of policy and decision-making. Using business analytics-based dashboards provides a user-friendly interface that enables stakeholders, policymakers, and decision-makers to interact with complex ocean data in a visually appealing and intuitive manner. By integrating diverse datasets, including oceanographic measurements, satellite imagery, climate data, and socioeconomic information, business analytics software dashboards facilitate the identification of trends, patterns, and correlations. By applying advanced analytics techniques, such as data mining, machine learning, and statistical modeling, these dashboards allow for the extraction of valuable insights regarding marine ecosystems, climate change impacts, pollution levels, and resource availability. The accessibility and interactivity of business analytics-based dashboards empower policymakers and decision-makers to explore different scenarios, evaluate the potential outcomes of various policies, and assess the implications of their decisions on ocean health and sustainability. Additionally, these dashboards facilitate the communication of complex data findings to stakeholders and researchers through visually compelling and informative visualizations. Implementing ocean data analytics as a service, supported by business analytics-based dashboards, presents opportunities for evidence-based decision-making, proactive policy formulation, and adaptive management strategies in the face of dynamic oceanic challenges. Integrating real-time data feeds into these dashboards further enhances their capabilities, enabling timely responses to emerging issues and facilitating informed decision-making in near-real-time. Overall,

ocean data analytics as a service and business analytics-based dashboards empower policymakers and decision-makers with comprehensive insights derived from vast and complex oceanic datasets. By harnessing the power of visual analytics, this approach fosters sustainable management of ocean resources, enhances environmental protection measures, and supports informed policy decisions to address the challenges and opportunities presented by our dynamic oceans.

Keywords: Data Visulaization, Data Analytics, Business Analytics, Decision-Making

A multidecadal study of the malabar upwelling system influencing Indian Mackerel catch along the coasts of Karnataka and Kerala, south-east Arabian Sea

[ABS-01-0196]

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The Malabar coast (southwest coast of India) is one of the major upwelling systems of the world where upwelling takes place during the monsoon months ensuing productivity to sustain a fishery for several commercially important fishes. This coast contributes to nearly 50% of the total Indian marine fish landings, characterized by mostly small pelagic fishes which support the western Indian Ocean's largest coastal pelagic fishery. Oceanographic information is important for effective fishing practices to maintain a sustainable fishery industry. Apart from main environmental factors influencing the availability, migration, feeding and reproductive activity of these small pelagic fishes, ocean mesoscale events are also known to influence their catch. For understanding the relationship between the target fishes and the oceanographic events, in the present study, Pearson's correlation has been estimated between Indian Mackerel-, anchovies- and total marine fish catch, rainfall, Sea surface temperature (SST), mixed layer depth (MLD) and occurrences of potential fishing zone (PFZ) lines along the Malabar upwelling zone corresponding to the coasts of Karnataka and Kerala, south-west coast of India. Good prediction and observation trends and significant correlation coefficients have been found between Mackerel landings and the above covariates in seasonal time lag. Upwelling events illustrated by rainfall and incidences of number of PFZ lines indicated more significant correlation on the landings of Indian mackerel, anchovies and total marine fisheries landings along the Karnataka and Kerala coast along the Malabar upwelling region. Multiple linear regression method shows that these covariates can capture the trend of Mackerel landings which elucidates the influence of these parameters on Mackerel catch.

Keywords: Malabar upwelling zone, Indian Mackerel, rainfall, SST, mixed layer depth, Pearson's correlation

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Inherent Optical Properties (IOP) of phytoplankton bloom in northern Arabian Sea during winter season using EOS-6/Ocean Colour Monitor-3 and Sentinel-3/OLCI

[ABS-01-0370]

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Arabian Sea is one of the productive basin of northern Indian Ocean region and experiences strong seasonality in terms of biological productivity. It has two high productive seasons i.e. winter season (December-March) and summer season (June-September) with two low productive inter-monsoon seasons (October-November) and (April-May) respectively. Phytoplankton blooms in the winter season occur due to winter cooling and vertical mixing of the water column. In this study, Inherent Optical Properties (IOP) of the Northern Arabian Sea (NAS) during winter season is analysed using Quasi Analytical approach (QAA) on remote sensing reflectances retrieved from Sentinel-3/OLCI and Oceansat-3/OCM data. Phytoplankton absorption characteristics derived from QAA indicate the occurrence of bloom conditions in NAS. During bloom conditions higher values of chl-a gives higher absorption in blue region and minimal to nil absorption in green region. A threshold value of low phytoplankton absorption coefficient at 555 nm (corresponding to high reflectance in green) along with high chlorophyll-value has been used for detecting spatial distribution of phytoplankton bloom using OLCI and OCM 3 data. With this approach, it has also been observed that peak bloom occurs during February in NAS compared to other months of winter season (December, January and March).

Keywords: NAS, bloom, QAA, IOP, Sentinel-3/OLCI, EOS-6/OCM-3

Accident causation models for capture fisheries Research: A comprehensive review using Haddon Matrix

[ABS-01-0486]

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Marine fishing is a precarious sector with high rates of occupational accidents, including both fatal and non-fatal injuries. Analyzing fishing occupational accidents is important for determining the causes of accidents and developing appropriate countermeasures. Many occupational accident models (OAM) and theories have been applied to analyze the causes of accidents in several industries. However, little is understood about the causes of accidents and safety issues among fishermen and their vessels. This study aims to introduce the role and origin of Linear Accident Causation Models (LACMs) and conduct a comprehensive review of the concepts of 11 representative linear accident causation models (LAM) proposed between 1931 and 2016 and their application status in the fisheries sector. A new method for classifying accident causation models is proposed by systematically segregating and interpreting parameters of LAM with the help of the Haddon matrix, which presents a conceptual model for the systematic exploration of countermeasures for a new classification of accident model for the fisheries sector. Starting with hazard meaning or identification, the root causes of accidents, accident causation framework, and management intervention strategies are presented progressively. This new model is called the Fisheries Hazard Identification, Forecasting and Avoidance Model (FHIFA), which focuses on the pre-event, event, early post-event, and late post-event stages. The study also discusses safety culture and prevention of accidents with an effective management system process for future applications. The research findings of the study are as follows: (i) The theoretical basis, application flow, and application status of these models in the marine fisheries sector are highlighted. (ii) The newly proposed classification method of the occupational hazard model clarifies the classification of accident causes in the fisheries sector and identifies prevention methods. (iii) Each

type of linear accident causation model has its own characteristics and application status in the fisheries sector, and the current linear accident causation models, including Model FHIFA, consist mainly of qualitative and quantitative analysis, which will help to prevent occupational hazards and accidents in the marine sector in the future

Keywords: Accident Causation Model, FHIFA, Linear Accident Causation Models

Evolution and recent trends of Indian oil Sardine research- Indian context

[ABS-01-0327]

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Among marine fishes Indian oil sardine (Sardinella longiceps Valenciennes, 1847), has a unique position in terms of its economic value for its importance as a favoured table fish and rich source of fish oils. In the last decade, it has contributed about 15 - 20% to the total marine fish landings in India, generating a revenue of approximately 350 crores. However, recently a sharp decline has been observed in the annual landing of the resource and is on the verge of collapsing due to climatic as well as anthropogenic perturbations as evident from the recent literatures. A cyclic pattern of wide annual fluctuation is observed by various researchers for this species. If we look back into the research activities on oil sardine it has a history dating back to 1924. To mine the information regarding past research endeavors a bibliometric analysis has been carried out by retrieving datasets from the Scopus database using a suite of keywords pertaining to oil sardine to understand the growth of literature, research area focuses, and research requirements. By scrutinizing all the important literature, a total 206 publications were included for the analysis. As apparent from the analysis previously the research focus was more on the physiology and biochemical characteristics of sardine and sardine oil whereas in recent times the focus is more on oceanographic parameters in relation to the life cycle of oil sardines in fact a clear gap could be observed in the habitat suitability research. Hence there is a need to track the environmental factors affecting their perturbations and to map the habitat suitability index for sustainable management practice.

Keywords: Oil sardine, Sardinella longiceps, Scientometric analysis, Literature review, India

Unveiling the Connection: How Cyclone Mocha Influence Jellyfish Stranding on Puri Beach of Odisha

[ABS-07-0301]

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Puri Beach, Odisha, located on the eastern coast of India, is a popular tourist destination known for its pristine shores and vibrant marine ecosystem. However, during a recent cyclone Mocha that hit from 9 May to 15 May 2023, a massive stranding of jellyfish on the shores of Puri Beach took place. The mass stranding of jellyfish event took place on 14 May 2023 (during the night), when the cyclone was about to take landfall on the Myanmar coast. The species was identified as Netrostoma coerulescens (Linnaeus, 1758). The present study provides a possible scientific basis for this event. The current mass beach stranding of Netrostoma coerulescens can be explained by offshore swarming and subsequent drift away to the beach due to shoreward water currents and wind speed. Satellite-retrieved Sea Surface Temperature (SST) data revealed a little higher water temperature (~29.60C) than previous days, which also might have influenced them to strand. The jellyfish swarms in the oceans can be attributed to several reasons like reduced predator and competitor populations, huge food resources, mating purposes, etc.

Keywords: Blue flag, SST, Current, Stranding, Satellite

Investigating Indian Oil Sardine run event in coastal waters of the southeastern Arabian Sea

[ABS-06-0337]

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The southwest coast of India experiences frequent Indian Oil Sardine (IOS) nearshore aggregation events, especially in coastal waters off Kerala. These ephemeral IOS aggregation events are known as 'Sardine Run' and is locally referred to as 'Chakara'. In order to investigate the reason and provide a scientific basis for these sporadic events, satellite/model-derived physical, meteorological, and biological parameters were analyzed. Sea Surface Temperature during 12 IOS run events among 14 was in the range of 26-29 °C agreeing with the reported temperature conditions for IOS in the Arabian Sea. Additionally, a marginal lowering of SST as an effect of precipitation prior to most of the events might have attracted IOS towards the near-coastal waters resulting in the run event. During most of the IOS run events, the wind and surface current direction was alongshore/coastward which aided in the propagation of live IOS shoals towards the beach.

Keywords: Sardine Run,Precipitation,Kochi,Current,SST

Detection and analysis of ionospheric signature of Turkey Earthquake

[ABS-01-0388]

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Ionospheric Total Electron Content (TEC) is a measure of the total number of free electrons in an ionized gas column in the Earth's ionosphere. It has been observed that surface deformation related to earthquake and tsunami propagation produces ionospheric changes in the total electron content. Studying TEC variations generated by an earthquake involves analyzing the changes in the ionosphere's electron density that occur as a result of an earthquake. Turkey and Syria, on 6th February 2023, witnessed one of the most devastating earthquakes in their history, leading to widespread damage and tens of thousands of fatalities. Two major earthquakes of magnitude M 7.8 and M 7.5 occurred in the transition between the Dead Sea fault and the East Anatolian fault. At 1:17 UTC, an Mw 7.8 earthquake struck southern Turkey near the northern border of Syria. The earthquake had a maximum Mercalli intensity of XII (Extreme) around the epicenter. It was followed by an Mw 7.5 earthquake at 10:24 UTC, approximately 90 km to the north. Studies on coseismic ionospheric disturbances associated with these events have shown some promising results of ionospheric TEC variations. Data from the IGS network located in Turkey and neighboring countries were considered for the study. These data are analyzed for 12 GPS stations surrounding the earthquake epicenter using GPS-TEC Software for Ionospheric TEC Extraction. A sudden drop in TEC a few minutes after the earthquake is noticed, and the variations are observed for a few hours after the event. The changes were prominent in the nearby stations, eg, Kars, Aruch-Yerevan, and Ankara, and the amplitude decreased further as we moved away from the epicenter. This study shows the importance of continuous TEC monitoring that will be used to detect earthquakes and Tsunamis in seismically active regions and support conventional systems. By continuously monitoring TEC variations, it is possible to detect anomalous changes in TEC that indicate impending seismic or tsunami activity, helpful for Tsunami early

warning systems that can alert people living in the affected regions and provide them with the necessary time to take protective measures.

Keywords: Ionospheric Total Electron Content, Turkey- Syria earthquake 2023, Tsunami early warning system, Continuous TEC monitoring, Coseismic ionospheric disturbances

Sub-Theme-02

Ocean Observations (In-situ & Satellite)

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Ocean surface vector winds from the ISROs latest scatterometer on-board EOS-06

[ABS-02-0051]

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Indian Space Research Organisation (ISRO) has launched its third scatterometer (SCAT3) mission on-board Earth Observation Satellite ¿ 06 (EOS-06, erstwhile Oceansat-3) on November 26, 2022. The SCAT3 follows its design heritage from Oceansat-2 Scatterometer (OSCAT, launched in 2009) and Scatsat-1 (launched in 2016). The payload hardware has been improved to accommodate a 1.4 m diameter antenna (in comparison to 1 m diameter antenna in both OSCAT and Scatsat-1). The larger antenna results in generation of the data products with better spatial resolution in nominal mode. The payload is capable to operate in an experimental high resolution (HR) mode which can generate the wind products with a spatial sampling of 5 km. Post launch, the Data Product Generation System (DPGS) is tested and installed at ISRO's Integrated Multi-mission Ground Segment for Earth Observation Satellites (IMGEOS) located at Shadnagar Campus of National Remote Sensing Centre (NRSC), Hyderabad. Data from the payload is received at multiple ground stations across the globe viz. Antarctica, Fairbanks, Svalbard and Tromso and is transferred through high-speed network links to Shadnagar, for generation and dissemination of data products. The payload operations has successfully completed In Orbit Testing (IOT) phase. Presently calibration and validation of the products are being carried out. Operational products including Level-1B (scan mode backscattering and associated data), Level-2A (backscattering and associated data over the satellite swath), Level-2B (ocean surface vector wind products over the satellite swath), and Level-3 S/W (daily backscattering /wind products averaged over the global geographical grid) are being disseminated from Bhoonidhi (https://bhoonidhi.nrsc.gov.in). Higher level value added products (e.g., global analysed winds, ocean surface currents, super-resolution backscattering and brightness temperature over the lands etc.) are being generated and disseminated from Meteorological & Oceanographic Satellite Data Archival Centre (https://www.mosdac.gov.in). Initial evaluation of the quality of the products

against NWP model analysis from National Centre for Medium Range Weather Forecasting (NCMRWF) and European Centre for Medium Range Weather Forecast (ECMWF) has been performed and it has been found that the quality of the products meets the mission specifications.

Keywords: EOS-06, scatterometer,oceansurafce wind

Development of sub surface tsunami buoy system for indian tsunami early warning application

[ABS-02-0269]

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Ocean Observation Systems group of National Institute of Ocean Technology maintains OMNI and Tsunami buoy systems in Bay of Bengal and Arabian Sea.The conventional tsunami buoy system consists of floating surface buoy system and bottom pressure recorder deployed at seabed. The surface buoy system installed at sea surface is prone to persistent harsh marine environment condition and are often observed to have damages and may result in scarcity of critical data. This surface buoy system suffers from biofouling and also it is exposed to extreme events such as cyclones. So, an innovative concept of maintaining the surface buoy system at 300m water depth was envisaged. Based on the mode from bottom pressure recorder, the sub surface buoy system operates an electrical underwater winch system for ascending the telemetry module to the surface. After the successful transmission of tsunamigenic data, the transmission module will be retracted to the original parking depth(300m). In order to ascertain the health of the system, the system performs ascending/descending operations every 15 days for transmission of health parameters and water level data. The logical sequence and the hardwares are developed .A laboratory scale prototype was successfully demonstrated at tank facility at NIOT and field validation of the system was completed at Idukki lake.This paper provides details of the design parameters, development of prototype and field validation.

Keywords: Tsunami, sub surface, underwater winch, cyclone,biofouling

Seasonal coastal and shelf circulation dynamics on the Western Bay of Bengal using HF RADAR and satellite-derived ocean currents

[ABS-02-0216]

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The monsoon system primarily drives upper ocean circulation in the north Indian Ocean with dominant spatial modes in the coastal and continental shelf regions around India, known as monsoon currents. The continental shelf of India in the north is wider and gradually narrows down to the south. The coastal and shelf circulation is highly modulated by tides, riverine fluxes and underlying bathymetry and geometry of the regions, making the circulation more complex with the presence of fronts and sub-mesoscale eddies. Analysis of the coastal and shelf circulation along Eastern continental shelf of India in the western Bay of Bengal (BoB) was investigated using in situ observations from current meter and High-Frequency Radar (HFR) systems, along with estimated currents from a simplified diagnostic model for ocean circulation driven by atmospheric forcing from satellite observation during 2015-2020. The ocean model has a reasonable agreement with the observed current patterns. The significant observations about the model solution were that the reversibility of the boundary currents is well captured along the western BoB, with the northward flowing western boundary current (WBC) during February-April and the southward flowing east India coastal current (EICC) during November- December along the western BoB coast. The intra-seasonal oscillations also predominantly comprise the signatures of 30-90-day oscillations (MJO during November-February), 10-20-day oscillations and 3-7-day synoptic signals. The investigation also explored the evolution mechanism of a mesoscale cyclonic eddy along the western BoB, focusing on Eulerian parameters. The study observed that the eddy originated due to baroclinic instability and analyzed its growth and intensification. Furthermore, tidal analyses demonstrated that the highest amplitudes of M2 tidal currents were observed along the western BoB coast, followed by other semi-diurnal (S2 and N2) and diurnal (K1, O1) tidal constituents.

Keywords: Ocean Currents, HF RADAR, EICC, Tide, Monsoon

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Intraseasonal variability of subsurface ocean temperature anomalies in the Indian Ocean during the summer monsoon season

[ABS-02-0010]

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The present study focuses on the variability of subsurface ocean temperature and associated planetary waves (oceanic Kelvin and Rossby waves) in the Indian Ocean during the boreal summer intraseasonal oscillation (BSISO) phases in the Indian Ocean Dipole (IOD) years. To accomplish this, multi-sensor datasets have been considered for the period 1980¿2021. During negative IOD (nIOD) years northward propagation of BSISO convection is consistent with the normal years, whereas incoherent patterns are evident in the positive (pIOD) years. Enhanced meridional gradient of sea surface temperature (SST) anomalies is evident during the nIOD years, which favours the coherent northward propagation of BSISO. Significant intraseasonal variations of subsurface ocean temperature anomalies are observed in the Equatorial Indian Ocean (EIO). Pronounced subsurface (50¿150 m) temperature anomalies are evident during the different phases of BSISO during the nIOD years. Symmetric formation of equatorial downwelling Kelvin wave followed by upwelling Kelvin wave packet were observed during the nIOD BSISO phases. This study further suggests that the symmetric patterns of subsurface waves are evident during the nIOD years and led to clear variations of the northward propagation of BSISO.

Keywords: Sea surface temperature, North Indian Ocean, BSISO, Indian Ocean Dipole.

Satellite-based sea surface density variations in the North Indian Ocean

[ABS-02-0217]

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KUFOS

Investigation of long-term (decadal) changes in Sea Surface Density (SSD) over the North Indian Ocean (NIO) is vital to understand its complex processes, its responses to the changing climate and its interaction with the ocean dynamics. Unfortunately, sparse and uneven distribution of in-situ sea surface salinity (SSS) observations, which are crucial for the estimation of SSD hindered such study over NIO till the satellite SSS era. However, in recent decades, uninterrupted SSS measurements from the space-borne sensors such as Soil Moisture and Ocean Salinity (SMOS), Aquarius and Soil Moisture Active Passive (SMAP) have overcome the limitation of in-situ observations. Recently, Copernicus Marine Service generated global SSD products by combining SSS information from SMOS, Aquarius, SMAP and in¿situ observations and satellite sea surface temperature products. The present study utilises these gap-free level-4 SSD products and explains SSD trends over NIO during 2010-2022. Although an overall increasing SSD trend of 0.11 kg/m3 is observed over entire NIO as whole, the trends in Arabian Sea and Bay of Bengal (BoB), which comprise NIO are different. A substantial fall of 0.28 kg/m3 is observed in the BoB and a modest increasing trend of about 0.01kg/m3 is noted over the Arabian Sea. Study shows the impact of huge inflow of fresh water discharge in declining SSD during monsoon and post-monsoon seasons in BoB. In addition, the dominant regions and modes of SSD variability through Principal Component Analysis and the impact of SSD variations on mixed layer depth and barrier layer thickness, the vital sub-surface processes of NIO are also explained. Study emphasises the potential of SSD obtained from satellite SSS and SST products in resolving ocean dynamics of NIO under the paucity of in-situ observations.

Keywords: Sea surface density, sea surface salinity, satellites, North Indian Ocean, decadal trends.

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Retrieval of Sea Surface Temperature and Atmospheric Profiles from INSAT-3DR: Comparing Bayesian inference, 1D-Var, and Machine Learning

[ABS-02-0219]

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Accurate measurement of Sea Surface Temperature (SST) is crucial for weather forecasting, climate analysis, and understanding ocean-atmosphere interactions. Additionally, monitoring diurnal variations in SST is essential for detecting and mitigating the impacts of marine heat waves on marine ecosystems. The commonly used NLSST algorithm faces limitations, regressing buoy SST against satellite-measured skin temperature while failing to account for errors caused by zenith angle variations adequately. Our study shows that these errors can be of a magnitude of 10K in extreme scenarios. We in this work present a comprehensive approach for remote Sea Surface Temperature (SST) measurement using the INSAT-3DR data that combines the power of Bayesian inference and the 1D-Var method, which allows for incorporating prior knowledge and uncertainties from a set of diverse atmospheric profile datasets and optimizes the retrieval process through an iterative approach by minimizing a cost function. The primary goal is to solve the inverse problem by implementing these techniques and a fast radiative transfer model like RTTOV to accurately measure atmospheric temperature, water vapor profiles, and SST using the INSAT-3DR data. We have developed an algorithm for joint retrieval of SST and atmospheric profiles that capitalizes on the synergy between observed radiances in different channels, enhancing retrieval accuracy. By utilizing the imager and sounder channels, we can obtain valuable information on atmospheric properties, enabling a comprehensive understanding of the atmospheric state and facilitating accurate SST estimates. To augment this approach, we have integrated machine learning techniques such as Artificial Neural Networks (ANN) and Random Forests. These methods offer the ability to learn complex patterns and relationships from the data, thereby improving retrieval. This study highlights the potential of satellite remote sensing for global monitoring of Earth's oceans and atmosphere.

Keywords: Retrieval, SST, Atmospheric Profiles, Machine Learning,1D- Var

Utilising VIIRS DNB sensor data for assessing natural and artificial light sources over the North Indian Ocean

[ABS-02-0245]

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The Visible Infrared Imaging Radiometer Suite (VIIRS) onboard the Suomi National Polar-orbiting Partnership (NPP) and NOAA-20 satellites include the Day/Night Band (DNB), specifically designed for capturing low-light conditions such as nighttime imagery. This study focuses on analysing the bright pixels observed over the ocean in the DNB band of VIIRS sensor data during the night, which can be attributed to a combination of natural and artificial light sources. Marine environments exhibit diverse light sources, including bioluminescence from phytoplankton species, bioluminescent bacteria, and artificial light sources like ships and fishing vessels. Through detailed investigations using VIIRS DNB data, we differentiate between these various sources of bright pixels in the ocean during nighttime. The Arabian Sea, renowned for its rich marine life and significance in fisheries, shipping, and oil exploration, experiences bioluminescent phenomena caused by marine organisms such as Noctiluca scintillans. These organisms generate luminous patches or trails in the water, visible as bright targets in the VIIRS DNB imagery during the night. The Indian National Centre for Ocean Information Services (INCOIS) has established an X-band Ground station to acquire VIIRS data, enabling in-house operational services and the generation of DNB products to support ocean surveillance and biological ocean studies. This research demonstrates the effective utilisation of VIIRS DNB sensor data, providing valuable insights into ecological dynamics and human impacts in this critical marine region.

Keywords: Bioluminescent,VIIRS DNB Sensor ,North Indian Ocean,Noctiluca scintillans

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Investigating the impact of optical radiative properties of aerosols on radiometric calibration: Insights from Oceansat-2/OCM2 and Oceansat-3/OCM3 Sensors

[ABS-02-0286]

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The optical radiative properties of aerosols play a crucial role in accurately calibrating satellite sensors for Earth observation. This study aims to investigate the impact of these properties, which are derived from ground-based measurements using the Cimel CE-318 Sunphotometer, on the radiometric calibration of OCM2 on board Oceansat-2 and OCM3 on board Oceansat-3 (EOS-06) satellites. Calibration campaigns were conducted in January 2023 at the Little Rann of Kutch (LROK) in Gujarat, India, to obtain simultaneous measurements of surface reflectance and atmospheric variables. Additionally, a comprehensive dataset acquired between 2014 and 2023 over a desert site called Desalpar (23.74°N, 70.69°E, 30 m m.s.l.), which is located 70 km away from the LROK site, was analyzed to explore the relationship between optical radiative properties and the accuracy of radiometric calibration. To assess the calibration performance of both sensors under various atmospheric and aerosol conditions, we utilize the advanced Radiative Transfer Model known as 6SV. Results revealed aerosol optical depth (AOD550) and Angstrom exponent (AE440-870) during DJF (0.25+0.09) and (1.45+0.17), indicating the dominance of fine-mode aerosols from the desert. Additionally, the aerosol volume size distribution (VSD) increased with an increasing AOD, exhibiting a bimodal lognormal structure with a more pronounced peak in fine-mode particles relative to coarse-mode particles. Furthermore, our findings provide significant insights into the influence of optical radiative properties on radiometric calibration. We observe that variations in properties such as aerosol scattering and absorption characteristics have a significant impact on the calibration accuracy of the sensors, particularly in the spectral bands ranging from 0.4 to 1.2μm in the electromagnetic spectrum.

Furthermore, we compare the radiometric calibration performance between Oceansat-2/OCM2 and Oceansat-3/OCM3 sensors. Through rigorous analysis, we identify potential improvements in the radiometric calibration process for Oceansat-3/OCM3, which leads to enhanced data accuracy and reliability by 2%. Overall, this study provides valuable insights into the impact of optical radiative properties on radiometric calibration, highlighting the importance of considering these properties for accurate observations. The findings contribute to advancing the calibration techniques and strategies employed in satellite sensors, ultimately improving the quality of remote sensing data obtained from Oceansat-2 and Oceansat-3 satellites.

Keywords: Oceansat-2 and Oceansat-3, Radiometric calibration,6SV RT Model, Optical and radiative properties, Cimel CE-318

Potential of EOS-04 C-band SAR for mapping Algal blooms-Comparison with in situ and optical sensors

[ABS-02-0300]

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Regular monitoring of Algal Blooms is essential for an effective management of coastal and marine resources. Conventional methods have been developed for Algal bloom mapping and monitoring by optical ocean color sensors which are in coarse resolution, and lack the finer scale details of sub meso-scale features. Moreover, optical sensors will not be able to provide Algal bloom information during cloudy conditions. On contrary the Synthetic Aperture Radar (SAR) payloads having high resolution, day and night coverage, cloud free and all weather capability will provide unique opportunity to map ocean features such as Algal blooms. Accordingly, this study is aimed to use the EOS-04 C-band SAR data to demonstrate its potential, for the first time, in mapping and monitoring of the algal blooms in the Arabian Sea. Over the northern Arabian Sea, the presence of intense algal blooms is generally observed during winter (February). Using EOS-06 Ocean Color Monitor (OCM-3) RGB images during 9 February 2023 we observed an algal bloom event in the Arabian Sea. Coinciding data from EOS-04 SAR, EOS-06 OCM-3 and OCEANSAT-2 OCM-2, providing a unique opportunity to study the synoptic feature comparison of the imaging of algal blooms in the Arabian Sea by multi-sensory approach. The advantages of the EOS-04 C- band SAR data is its high resolution (33 m). EOS-04 SAR images in HH polarization in Medium Resolution Mode have been used in analysis.The blooms which are biogenic in nature show strong wave damping capabilities and appear as dark signatures with eddies in the SAR images. The backscatter intensity changes across the diameter of these eddies due to intense convergence and divergence zones due to swirling motion of eddies are analysed and discussed in the present study. These sub-mesoscale eddy features captured in SAR data are matching, in position and size, with the OCM-3 data. The synergistic use of SAR and optical data gives additional information and confirms the capability SAR to capture these bloom related signatures. In situ Bio-Argo profiles containing the information about Chlorophyll-a in the Arabian Sea have also been analyzed for further understanding of the dynamics of these Algal blooms.

Keywords: EOS-04, SAR, Algal blooms, EOS-06, OCM3, Arabian Sea, meso scale

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Post-Launch validation and performance assessment of EOS-06 scatterometer wind vectors using In-situ, ASCAT and NWP winds

[ABS-02-0456]

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The Indian Space Research Organization (ISRO) launched the EOS-06/Oceansat-3 satellite, as a follow-on mission to Oceansat-2, on 26 November 2022. There are three sensors on the satellite for earth observation, viz, Ocean Color Monitor, (OCM-3) and SCAT (scatterometer), and Sea Surface Temperature Monitor (SSTM). This study focuses, for the first time, on evaluating the first operational version of EOS-06 SCAT (The only scatterometer present at 12:30 AM/PM Orbit) wind vectors with observations from various global moored buoys, including the U.S. National Data Buoy Center (NDBC), the Tropical Atmosphere Ocean (TAO), the Pilot Research Moored Array in the Tropical Atlantic (PIRATA), the Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction (RAMA), as well as Advanced Scatterometer (ASCAT) and ECMWF Analysis winds. The comparison between EOS-06 SCAT wind vectors and the global ECMWF Analysis, Buoy and ASCAT wind measurements involves calculating statistical parameters such as the root mean square error (RMSE), bias (mean of residuals), and correlation coefficient (R) using the collocated data. The findings reveal that EOS-06 SCAT winds exhibit consistency with other contemporary wind measurements. The average RMSE for EOS-06 SCAT wind vectors are determined to be 1.5 m/s for wind speed and 16° for wind direction which is in closer agreement with the satellite's mission specifications of <1.8 m/s for wind speed and 20° for wind direction. Further analysis of the EOS-06 SCAT wind vector errors at different wind speed regimes, categorized in 1 m/s bins, reveals a trend where the accuracy of EOS-06 SCAT wind speed is initially lower for wind speeds <3 m/s and improves for winds 3-18 m/s and then declines with increasing wind speed. Additionally, a comparison between EOS-06 SCAT wind vectors and ASCAT wind

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vectors indicates that the average RMSEs of their differences are 1.9 m/s for wind speed and 24° for wind direction. Furthermore, the ability of EOS-06 SCAT winds to capture the characteristics of cyclonic storms named MONDOUS, MOCHA, and MAWAR in December 2022 and May 2023 is also demonstrated. Overall, the accuracy of EOS06-SCAT wind vectors meets the general requirements of scatterometer missions and is consistent with other contemporary missions.

Keywords: EOS-06, Scatterometer, Ocean Surface Winds, Buoy, ASCAT

Retrieval of wave parameters from ICESat 2 observations along Kerala coast; Seasonal changes and coastal dynamics

[ABS-02-0361]

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The analysis of Significant wave height along the Kerala Coast using ICESat 2 data provides valuable insight into the wave characteristics of the region. By utilizing the photon Counting LiDAR instrument onboard ICESat-2 and the ALT03 data product, detailed information on wave heights can be obtained. The ALT03 data provide precise geolocation of laser photons detected by satellite, allowing for detailed measurement of the ocean surface. Using Icesat-2 data sets, we estimated wave parameters over four-year period from 2019-2022 along the Kerala coast. Geiod corrected ALT03 data are analysed to remove the outliers and filters were applied prior to the estimation of wave parameters, where subset of ALT03 data between bathymetry contours were taken to study the cross-shore variation of the ocean waves. Significant waves are estimated as the average of the highest 3 wave crest and also using the variance method, which are validated using numerical models. The study have brought out spatio-temporal dynamics and seasonal variations of the wave parameters. The ICESat-2 observations were able to resolve coastal wave properties like wave setup along the shoreline where radar altimeters get affected due to land proximity. Compilation of the wave parameters derived using ICESat-2 observations can significantly improve the wave observation database, especially near to the coastal region where radar altimeters get affected by the land proximity.

Keywords: ICESat2, Laser Altimetry, Coastal Wave Dynamics, Kerala Coast, Seasonal Dynamics

OCM - 3 In- Situ validation: Leveraging remote sensing for enhanced accuracy

[ABS-02-0237]

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The accurate monitoring of ocean color plays a crucial role in understanding the dynamic nature of marine ecosystems and their response to environmental changes. The Ocean Color Monitoring-3 (OCM-3) satellite, equipped with advanced remote sensing capabilities, provides valuable insights into the optical properties of the oceans. In this study, we present a comprehensive analysis of the correlation between ground truth data and OCM-3 satellite remote sensing data, aiming to improve the accuracy of ocean colour monitoring. Over a period of three months, extensive ground truth data was collected using in-situ measurements and sampling campaigns in specific regions of interest. Simultaneously, the OCM-3 satellite acquired high-resolution remote sensing data, capturing the spectral signatures of ocean color across the study area. The collected ground truth data and corresponding OCM-3 satellite remote sensing data were subjected to a rigorous comparative analysis. Key parameters such as chlorophyll-a concentration, suspended particulate matter, and sea surface temperature were evaluated to assess the agreement and correlation between the two datasets. Statistical techniques including regression analysis and correlation coefficients were employed to quantify the relationship and identify any systematic biases or discrepancies. Preliminary results indicate a significant correlation between the ground truth data and OCM-3 satellite remote sensing data, validating the satellite's capability for accurate ocean color monitoring. The findings highlight the potential of OCM-3 as a reliable tool for assessing variations in oceanic optical properties on a broader scale. Furthermore, the study demonstrates the value of integrating ground truth data with satellite observations, providing a comprehensive understanding of the observed oceanic processes. This research contributes to the advancement of ocean color monitoring techniques by establishing a robust framework for combining ground truth measurements with satellite remote sensing data. The integration of these datasets enhances the accuracy of ocean color

monitoring, allowing for improved characterization and assessment of marine ecosystems, water quality, and environmental changes. The results of this study have implications for a wide range of applications, including fisheries management, ecosystem modelling, and climate change studies.

Keywords: Ocean color monitoring, OCM-3 satellite, remote sensing, ground truth data, correlation analysis, optical properties, environmental changes.

Seasonal and intraseasonal modulation of near inertial wind power associated with fluctuation in the unidirectional wind speed in Bay of Bengal

[ABS-02-0059]

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This study examines seasonal and intraseasonal modulation of near-inertial wind power associated with fluctuations in unidirectional wind speed in the Bay of Bengal. For that purpose we used concurrent measurement of high-resolution in-situ near-surface current and wind speed from six moorings in the Bay of Bengal. It is found that the annual mean of near-inertial wind power in the Bay of Bengal shows roughly similar magnitude (0.3-0.4 mWm-2) at all the mooring locations, though well-defined annual variability with a maximum during summer (~0.6-0.8 mWm-2) and fall (~0.3-0.4 mWm-2) and a minimum during winter (~0.1 mWm-2) and spring (~0.2 mWm-2) is noticed mainly in the northern Bay of Bengal. In the southern Bay of Bengal, the seasonal cycle in near-inertial wind work is relatively minor, with magnitudes ranging from 0.2 mWm-2 - 0.3 mWm-2. It is also found that monsoon intraseasonal oscillation (MISO) modulates near-inertial wind power, such as its magnitude reaching as high as 1.3-1.6 mWm-2 at the moorings in the northern Bay of Bengal during phases 3-4 of MISO, owing primarily to an increase in unidirectional wind speed magnitude. Furthermore, utilising a high vertical resolution of current data, the near-inertial Kinetic Energy (NIKE) budget in the mixed layer in the northern Bay of Bengal revealed that the magnitude of the rate of change of NIKE is smaller than that of near-inertial wind power. The disparity in NIKE in the mixed layer and near-inertial wind work is thought to be related to the quick propagation of a significant fraction of near-inertial energy into the interior of the Bay of Bengal.

Keywords: Near inertial wind power,Near inertial kinetic energy budget

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Role of long-term temperature/salinity observations in the Bay of Bengal in understanding various oceanic processes

[ABS-02-0140]

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Under Ocean Observations Network, an unprecedented collection of nearly 30 years of near-monthly repeat XBT/XCTD sections across the southwestern (Chennai-Port Blair) and north-western boundaries (Port Blair¿Kolkata) of the Bay of Bengal (BoB) has helped to understand various oceanic process of the Bay of Bengal in the recent decade. The data depicted the interannual variability of the East India Coastal Current associated with the IOD events, with poleward anomalies during positive IOD (pIOD) years and equatorward anomalies during negative IOD (nIOD) years in the post-monsoon season. The striking finding revealed by this data was the dominance of non-seasonal variability of EICC over seasonal variability. The repeat XBT sections along the Chennai-Port Blair transect exhibited seasonal and interannual variability of the near-surface layer thermal structure in the southwestern boundaries of the BoB. The satellite-derived sea surface height anomalies (SSHA) and observed thermocline depth show a distinct annual cycle composed of alternate downwelling (Jan¿June/July) and upwelling (June/July¿December) signatures. The thermocline shoals (deepens) up to 40-50m (110-120 m) depth with temperature anomalies ranging from -1oC to -2.8oC (1oC to 2.8oC) during upwelling (downwelling) wave propagation. The monthly repeat XCTD sections (2007-2020) across the northeastern part (Port Blair ¿Kolkata transect) of the BoB is used to examine the evolution of thermal inversion (TIs) and their inter-annual variability. Large (thickness ~ 71 m) and intense inversions (amplitude 2.3oC) are occurring relatively at shallow depths (~ 50m) during positive Indian Ocean Dipole (pIOD) years when compared to negative (nIOD) and neutral IOD (neutral) years. Inversions are intense in the northern BoB and gradually weaken towards the Port Blair regions. Further, the 30 years of XBT coverage between Chennai-Port Blair has helped to depict the decadal variability in the

southwestern bay. Apart from the XBT/XCTD data acquisition, the coastal and open ocean sea surface salinity data collection in this observational program has helped to identify the presence of 'River in the Sea' along the east coast of India and also assess its year-to-year variability modulated by the IOD.

Keywords: Temperature, XBT, Salinity, XCTD, IOD, Inversion, River in the Sea

An observational analysis of the characteristics of wind gust factor in the Bay of Bengal and Its implications on bulk air-sea flux estimates.

[ABS-02-0380]

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Wind gusts are the abrupt increase in wind speed, often caused by convective processes, frontal systems, or local topography, and are often represented by an estimate called Gust Factor (GF). GF is calculated as the ratio of peak wind speed to mean wind speed within a suitable averaging period. In this study, using high-frequency mooring observations, a comprehensive analysis of GF over the Bay of Bengal and its seasonality and implications on air-sea fluxes is done. It is found that GF is having a clear bi-modal seasonality with peaks in pre-monsoon and post-monsoon seasons. During the summer monsoon season when the winds are strong, GF is found to be less compared to other seasons. A novel method for GF estimation from mean winds across the basins following AI/ML tools is developed. It is found that the non-inclusion of the GF in air-sea flux calculation grossly underestimates the flux magnitude. Our analysis suggests that air-sea heat fluxes calculated using the state-of-the-art COARE3.5 bulk flux algorithm underestimate the fluxes by ~50 W/m2. This study advocates that GF is an important determinant of the accuracy of air-sea fluxes and should be considered for bulk air-sea heat flux estimation.

Keywords: Air sea interactions ,Ocean Observations ,Bulk estimations ,COARE3.5,Wind gust factor

A BGC-Argo based chlorophyll climatology for the northern Indian Ocean

[ABS-02-0411]

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A three-dimensional chlorophyll climatology is generated using the BGC-Argo measured chlorophyll profiles in the northern Indian Ocean. Nearly 8263 profiles from 63 BGC-Argo floats deployed during 2012 ¿ 2020 are used to generate this climatological gridded product using objective analysis. Towards this direction, this is the first 3-dimensional gridded product of chlorophyll for the northern Indian Ocean. The known signatures of the chlorophyll variability on a monthly scale are well represented in this product thereby re-affirming the quality of the product. The spatial distribution of chlorophyll on a monthly scale at different depths has depicted the signatures of upwelling, convective mixing in the Arabian Sea (AS) and the river runoff in the Bay of Bengal (BoB). Further, the depth integrated chlorophyll of the top 200 m has shown the abundance of chlorophyll in both the basins. The depth and concentration of Deep Chlorophyll Maximum (DCM) have captured the dynamics of DCM with time in terms of both depth and profusion of chlorophyll on a spatial scale in this region. The depth-time sectional plots on meridional and zonal directions have shown the chlorophyll variability along the length and breadth of both AS and BoB, thereby substantiating the known signatures as well as the scales of variability. The present study has shown the utility of synergistic application of both satellite and in-situ chlorophyll observations to arrive a good-quality gridded product that could serve as a base data for future data products. Further, this exercise could serve as a prototype and could be enhanced in quality by incorporating the observations that are available with time for better ocean productivity related studies in this region. This product will be updated on regular basis with in situ measurements from BGC-Argo and the newly available data from Gliders operating in the northern Indian Ocean. This will act as a good initial condition for biogeochemical ocean models which is hitherto not available as of now.

Keywords: BGC-Argo, Chlorophyll, Climatology, Northern Indian Ocean

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Deep sea gliders observations in the Bay of Bengal under Deep Ocean Mission (DOM)

[ABS-02-0488]

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To grow our marine and maritime economy, tackle climate change and pollution, and improve our sustainable use of resources, the Government of India has launched an ambitious programme entitled ?Deep Ocean Mission (DOM)? led by the Ministry of Earth Science (MoES). This mission has six verticals including a specific vertical related to the ?Development of Ocean Climate Change Advisory Services (OCCAS)? and Deep Ocean Observations is one of the component among OCCAS which will be coordinated by the Indian National centre for Ocean Information Services (INCOIS) with the following objectives (i) to monitor the deep ocean physical and biogeochemical parameters in northern Indian Ocean, (ii) to understand the temporal and spatial variability of Oxygen Minimum Zone (OMZ) and (iii) to monitor water mass properties and ventilation processes of the North Indian Ocean.

Keywords: DOM, OCCAS, ORV Sagar Nidhi , glider, deep sea gliders

Role of met-oceanic response to intensification of tropical cyclone Tauktae and Yaas

[ABS-02-0210]

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Tropical cyclones (TCs) are one of the most catastrophic natural disasters with severe weather systems, resulting in significant loss of life and property. In recent decades, the north Indian Ocean has been witnessed as having a significant influence on regional and global climate variability. However, the physical mechanism responsible for the rapid intensification of TC are highly challenging. The TC Yaas has rapidly intensified as compared to Tauktae, where the physics and dynamics are very important in order to predict TC landfall with reasonable accuracy. The present work examines the physical response of the surface met-ocean variables during the tropical cyclone Tauktae and Yaas over the eastern Arabian Sea (AS) and the western Bay of Bengal (BoB), respectively using multi-platform observation and modelling data. Atmospheric condition, oceanic subsurface mixing, energy advection, and air-sea fluxes are examined using mixed layer heat budget analysis for both the TCs. The difference between the 200- and 850-mb wind vectors during both cyclones were analysed to assess the contribution of ambient vertical wind shear. The TC Yaas required 1.5 days to intensify from a cyclonic storm to very severe cyclonic storm whereas, the TC Tauktae required 3 days to reach its peak to an extremely severe cyclonic storm. The present study suggests that vertical wind shear plays a significant role in transporting heat and moisture in order to rapidly intensify the TC Yaas.

Keywords: Tropical cyclones,Vertical wind shear,air-sea fluxes,Tauktae,Yaas

Use of geospatial technologies for Ocean Observation Networks (OON)

[ABS-02-0294]

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Making decisions based on geography is fundamental to human thinking. Where we should go, what it will be like, and what we will do when we get there are applied to activities ranging from a simple event like going to a store to a major event of launching a bathysphere into the ocean's depths. By understanding geography and people's relationship to location, we can make informed decisions about how we live on our planet. A Geographic Information System (GIS) is a technological tool for comprehending geography and making intelligent decisions. GIS organizes geographic data in such a way that a person reading a map can select the data necessary for a specific project or task. A thematic map has a table of contents that allows the reader to add layers of information to a basemap of real-world locations. An effective disaster management system requires solutions and approaches that allow efficient and reliable access to spatial data. Timely access to and sharing of accurate information for the purpose of disaster mitigation, prevention, preparedness, response, and recovery have proven to be a challenge in many recent disasters. From routinely performing work-related tasks to scientifically exploring the complexities of our world, GIS gives people the geographic advantage to become more productive, more aware, and more responsive citizens of planet Earth. This paper will illustrate how geospatial technologies are used to display the response of the ocean to tropical cyclones. In this approach, a dedicated WebGIS interface has been developed that integrates the various spatial layers derived from in situ (moored buoys, sea level data from tide gauges, and the latest data from Argo floats) and remote sensing (composites of satellite data and other derived parameters) observations. This WebGIS interface is a one-stop-shop for information on what is going on in the ocean and atmosphere during the passage of a cyclone. The products displayed in the viewer are highly useful in correlating the high-wave alerts issued by INCOIS and cyclone bulletins issued by the meteorological department.

Keywords: Website, Disaster Management, Advisories, Cyclone

Strength analysis of retrieved mooring rope from data buoy systems

[ABS-02-0094]

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The National Institute of Ocean Technology (NIOT) has a program on operation and maintenance of data buoys in coastal and deep waters to collect Met-Ocean parameters and Tsunami monitoring.This research paper presents the experimental mooring rope evaluation under SEM studies of the surface morphology following damage. The mooring system is a combination of various types of ropes connected by suitable mooring hardware. The NIOT buoys use a mooring scope (Total mooring Length/ Ocean Depth) of greater than 1m so as to maintain the stability of the moored buoys. The Coastal buoy mooring deployed by NIOT OOS uses a total mooring length of 1.5 ¿ 2 times the depth at the deployment location. The full mooring consists of combination wire rope and chains in the NIOT Coastal buoy network. Ocean Moored buoy Network for Northern Indian Ocean (OMNI) mooring is a single point mooring with Inverse catenary configuration (Slack mooring or S-mooring) with the mooring scope of 1.22. The BD-11 buoy is deployed at a depth of 3250 m in the Bay of Bengal at a distance of 231 nm from Chennai (13º28¿N and 084º¿E). The coastal buoy is deployed at a depth of 14 m in the Bay of Bengal at a distance of 1 nm from Chennai (13º05¿N and 080º18¿E). The combination wire rope, having Polypropylene sheathing on the metal rope, is used for connecting the deep or coastal surface buoys and to avoid failures due to fish bites in the subsurface region. When the wire rope failure occurred after the deployment period of over a year, the combination wire rope was retrieved, inspected and sectioned on both sides of the failure. To determine the reason for the failure, samples from the damaged rope were analyzed using visual inspection, SEM and hardness tests and thereby establishing a relationship between test parameters and fracture modes. The wire quality by itself is not the reason for failure but exposure to sea water corrosion and the failure of the plastic coating to protect underneath the steel wire is the main reason for failure of the overall wire rope.

Keywords: Scanning Electron Microscope (SEM), Ocean Observation Systems (OOS), Mooring Scope, Ocean Moored buoy Network for Northern Indian Ocean (OMNI), Inverse Catenary Mooring

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Bio-optical characteristics in the coastal waters of Kochi, South Eastern Arabian Sea: Role of phytoplankton community size structure

[ABS-02-0119]

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Based on the fluctuations in phytoplankton size, the bio-optical properties of coastal waters off Kochi, South Eastern Arabian Sea, were investigated. Bathymetry of the area affects the absorption by total phytoplankton, i.e., as depth increases, absorption decreases. Additionally, the findings demonstrated that microphytoplankton showed highest absorption at 443nm during monsoon, while nanophytoplankton showed variable rate of absorption. Chl a concentration was at their maximum during monsoon. Relatively cool water temperatures encouraged the diatom growth, particularly in surface water. The algorithm for identifying chlorophyll concentration of phytoplankton size fractions using total chlorophyll concentrations were fine-tuned and validated. Correlation between fitted and predicted value for chlorophyll concentration of microphytoplankton was 0.861, that of Nanophytoplankton was 0.842 and of Picophytoplankton was 0.779. Distribution of N, P and Si was also used to analyse size fractionated chlorophyll. The proportion of phosphate to silicate has increased. Rather than the ratio of inorganic nitrogen to phosphate, the ratio of silicate and phosphate has had an impact on the dynamics of phytoplankton. Findings of this study can help advance satellite remote sensing by providing knowledge on the bio-optical variability of size fractionated phytoplankton and its impact on nutrients in the coastal waters off Kochi.

Keywords: Absorption, Phytoplankton, Chlorophyll, Bio-optics, Arabian Sea

Measurement of flow characteristics along tidally dominated river at the Gulf of Khambhat

[ABS-02-0323]

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The Gulf of Khambhat is one of the highest tidally dominated regions located along the west coast of India, where field measurements play an essential role in understanding hydrodynamics and circulation patterns. In the present study, a comprehensive field measurement campaign has been carried out to understand the flow characteristics of the Auranga River located along the Gulf of Khambhat. The parameters such as tides, waves, and currents were observed from 26th November 2019 to 1st December 2019 during the post-monsoon season. In order to achieve this, two Acoustic Doppler Current Profilers (ADCP) and multiple tidal gauge sensors were deployed both inside and outside of the river channel. In addition, a Lagrangian-based drogue experiment was also carried out to observe the surface flow patterns along the river during the flood and ebb-tidal cycles. The observed results indicated that the maximum current velocity is 1.2m/s and 0.7m/s at the outside and inside of the river, respectively. Moreover, it is noted that the water level difference of nearly 3m was observed from inside measurement compared to outside due to tidal asymmetry characteristics. The findings from this study will be further used for the validation of the numerical modeling study. The details of the field measurement, methodology, and results are discussed in the full paper.

Keywords: Auranga river, hydrodynamics, field observation, tidal currents, drogue experiment

Unveiling the Intriguing Characteristics of the Alappuzha Mudbank Region during the Winter Monsoon

[ABS-02-0405]

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The mudbank regions along the Southwest Coast of India in the Arabian Sea are characterized by unique geological phenomena and play a crucial role in supporting local fisheries. In this study, an exclusive field survey was conducted on 23 rd November 2021 and 16 th December 2021 in the coastal waters of Alappuzha Mudabank (stations S2, S3, S4, and S5). Seabird SBE 19 plus CTD was used to measure the temperature, salinity, PAR, turbidity and fluorescence profiles along a single transect covering 5 m (S2), 10 m (S3), 15 m (S4), and 20 m (S5) stations. The dataset portrayed the environmental characteristics during the winter monsoon with a subsurface maxima fluorescence in the November observation, which disappeared during December and was noticed by the presence of low saline (<32 psu) water column in the entire inner shelf region. The fluorescence-maximum zone well coincided with the subsurface salinity during November due to a delay in the upwelling retrieval, but in December, an oligotrophic environment was noticed. The vanishing of the fluorescence-maximum zone within a short period led us to investigate it by computing correlogram analysis and principal component analysis. The analysis indicated that increased salinity was the primary factor controlling the fluorescence-maximum zone, while lowering the salinity created an oligotrophic environment. We analyzed the satellite images from SMAP during this study period and found that the waters observed during December originated from the Bay of Bengal region. The average salinity recorded during December in the CTD and SMAP was 31.03 psu and 31.19 psu, further confirming the intrusion of Bay of Bengal water into the Arabian Sea. These observed inferences suggest the possibility of a notable influence of Bay of Bengal intrusion on the environmental conditions and productivity of the Southeastern Arabian Sea region.

Keywords: Mudbank, Fluorescence, Salinity, Bay of Bengal, Arabian Sea

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Design and installation of a smart Automatic Weather Station (AWS) at NIOT campus

[ABS-02-0440]

Arul Muthiah M, G. Vengatesan, K. Ramesh, Biswajit Haldar, B. Kesavakumar, Amit R. Chavan*, Tata Sudhakar
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Automatic Weather Stations (AWS) are extensively used for gathering meteorological and climatic data. The World Meteorological Organization (WMO) provides the guidelines for the implementation, installation, and usages of these stations. Currently, there is an ever-increasing necessity for the implementation of automatic observing systems that will provide scientists with the real-time data for the proper environmental policy. In this regards, National Institute of Ocean Technology (NIOT) developed a smart automatic weather station to serve this purpose based on the decade of experience in development and maintenance of deep sea moored buoy system in the northern Indian Ocean. The system equipped with several meteorological sensors such as wind speed and direction, air humidity and temperature and rainfall. The data from these weather sensors are acquired by a low power data acquisition system and transmitted through a GPRS modem and uploaded to web server via FTP. The state of art graphical interface unit (GUI) designed by NIOT reads the files and displays the information provided by the web server in real-time. The data logger of this smart AWS system also uses advanced MPPT (Maximum Power Point Tracking) charge controller for automatic change over from lead acid to lithium battery sources and also an HMM (health monitoring module) to check the status of the microcontroller continuously to avoid any unexpected failure of the system. This AWS is also having the option to test and configure individual sensor through mobile application remotely. It will store the data internally if the signal strength is low and retransmit when the signal is recovered. The data from this station is also shared to India Meteorological Department in real time and the transmission interval will automatic change to high frequency rapid mode transmission during extreme cyclonic events which will helps IMD for better weather forecasting especially during extreme events. The system is already designed and installed at NIOT campus which is working satisfactorily till date.

Keywords: AWS, NIOT,MPPT, GPRS, IMD

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Characteristics of Tropical Cyclone in the North Indian Ocean using Scatterometer Winds.

[ABS-02-0465]

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The Scatterometer derived can overcome the limited coverage of in-situ observations from moored buoys and Doppler Weather Radar. The present work used the Scatterometer swath data of Level 2B and Level 4 daily analyzed wind of SCATSAT-1 with a spatial resolution of 25x25 km and 6.25x 6.25 km respectively to capture the surface level structure of the cyclone and maximum wind speed during the tropical cyclone (source: https://www.mosdac.gov.in/). The inter-comparison is done with OMNI buoys and was compared with ASCAT and the wind speed given by IMD from the year 2017 to 2020. Five cyclones in the northern Indian Ocean (Ockhi, Titli, Kyarr, Bulbul, and Amphan) are considered. The maximum wind speed recorded by SCATSAT-1 Scatterometer Level 2B swath data is up to 40 m/s whereas Level 4 and ASCAT daily analyzed wind can capture the maximum wind speed of 30-35 m/sec for the cyclone Amphan. The Scatsat-1 Swath-wise Level 2B wind data showed a good match when compared with the OMNI Buoy BD13 wind data during tropical cyclone Amphan by collocating both data. Further, this surface level daily analyzed wind observed by SCATSAT-1 Scatterometer was used for identifying the center of the cyclones based on a geometric method called the Winding-Angle Method and proposed the track of the cyclone. Further, the estimated track from Scatsat-I is reasonably matching with the track given by the IMD best track data. The work highlighted the importance of the Scatterometer wind data in cyclone research.

Keywords: : ScatSat-1, Scatterometer, Tropical Cyclone, Maximum Wind Speed, Cyclone Track, Cyclone Center.

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Sea Level Anomaly as a proxy to derive the depth of Upper OMZ variations along the eastern Arabian Sea

[ABS-02-0008]

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Information on the variability of depth of the upper oxygen minimum zone (OMZ; defined as DO <20 μM) is critical for understanding the magnitude and vertical extent of hypoxic zone. Herein, we have analysed the ship-collected year-long dissolved oxygen data from the offshore waters of the eastern Arabian Sea (EAS), along with the sea level anomaly (SLA) data from satellite altimeter, to exhibit the correlation of upper OMZ depths with the SLA. A strong positive correlation was observed between the depths of upper OMZ and SLA with a strong spatial heterogeneity. Annually, the depth of upper OMZ and SLA were highly correlated in the south EAS (R2 = 0.74) and central EAS (R2 = 0.89), but such a strong correlation in the north EAS (R2 = 0.74) was restricted to the periods other than winter monsoon when deep convective mixing oxygenates the upper OMZ. Accordingly, we propose a regression equation between SLA and upper OMZ, which can be used to estimate the depth of upper boundary of OMZ in the EAS. Considering the importance of monitoring the vertical expansion of OMZ and the difficulty in getting such in-situ measured oxygen data, we believe using SLA as a proxy to derive the upper boundary of OMZ would be much helpful in monitoring the OMZ variations in an ocean warming scenario.

Keywords: oxygen minimum zone, Arabian Sea, insitu measruments, sea level anomaly, Indian EEZ

Intercomparison of OCM-1 and SeaWiFS Remote Sensing Reflectances

[ABS-02-0190]

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To generate climate quality geophysical products from satellite ocean color sensors reprocessing of the data, algorithms fine tuning, update the ancillary data sources, and other changes that improve the quality of the product from time to time is needed. To evaluate such derived data products we need to compare with the available contemporary ocean colour sensors data. In this study OCM-1 derived Remote Sensing Reflectance (Rrs) of 443nm, 490nm, 510nm, 555nm with Sea-WiFS has been compared for the years 2000 and 2001 using the monthly binned products. As OCM-1covers the Indian Ocean region, comparison has been made over the Arabian Sea and Bay of Bengal only. From this study, it is observed that, OCM-1 Rrs were well correlated over many oceanic regions with Sea-WiFS in all the bands. However, overestimation is also observed in some bands. Comparison of the above mentioned bands of these two sensors is essential as they paly a major key role in estimating the chlorophyll-a concentration and also for IOPs (Inherent Optical Properties)

Keywords: OCM-1 ,SeaWiFS , Remote Sensing Reflectance (Rrs)

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How do the seasonal forcings control the estuarine turbidity maximum zone in the Cochin estuary?

[ABS-02-0403]

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Estuaries serve as transitional zones between freshwater and marine environments, characterized by dynamic physical and biogeochemical processes. ETMs play a crucial role in influencing estuarine sediment transport, nutrient cycling, and primary productivity. The Kochi Estuarine system, located on the southwest coast of India, represents an ideal study site for investigating the seasonal shifts of the ETM due to its numerous rivers, strong tidal regime, complex geomorphology, and diverse marine life. Monthly in-situ CTD data collected from June 2008 to May 2009 along the Kochi estuary revealed the presence of ETMs near the mouth during June-September due to high river efflux. ETM shifted towards the far from the inlet due to the saline incursion during March-May. Multi-sensor optical remote sensing techniques, such as the semi-empirical single-band turbidity retrieval algorithm developed by Nechad et al. (2009), was employed to validate in-situ observations. ETM in the satellite imageries correlated (0.8) well with the observed ETM, which gave confidence in monitoring and effective predicting of ETMs in the estuary. The satellite images confirmed the shifting of the maximum turbidity zone to the far reaches influenced by the saline incursion. Apart from satellites, numerical model studies simulate the stratification patterns within the Kochi estuary, considering factors such as river input, tidal mixing, and freshwater-saltwater interaction. The model results portrayed the vertical distribution of temperature and salinity gradients, indicating the presence and extent of ETMs.

Keywords: ETM, Tidal Regime, Turbidity, incursion.,Estuary

Long term changes in the Total Suspended Matter along the Indian coastal region

[ABS-02-0360]

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The sediment influx from river into the coastal region plays a crucial role in shaping the coastal landforms, stabilization and growth of deltaic regions, bringing nutrient influx and maintaining the biodiversity. Natural changes like climate change induced alteration in precipitation pattern, river channel modifications and human impacts like dam constructions, deforestation and changes in agricultural practises shall lead to changes in the sediment input to the coastal environment. We have analysed the long-term changes in the concentration of total suspended matter (TSM) along the coastal region of the Northern Indian Ocean. Level 3 Standard Mapped Image of MODIS-Aqua from 2003 to 2020 in Google Earth Engine is used to study the long term changes in the sediment influx. The TSM is estimated based on Tassan algorithm using Rrs 488; Rrs 555 and Rrs 667. Average of the TSM concentration is maximum along the Gulf of Khambhat, followed by Gulf of Kachcch and Ganga-Brahmaputra delta. Trends in the TSM is estimated and it is observed that for both Arabian Sea and the Bay of Bengal the TSM shows decrease in concentration from 2003 to 2020. From the basin wise analysis, the negative trend in TSM concentration is highest along the Gulf of Khambhat. Ganga-Brahmaputra deltaic region shows maximum decreasing trend in TSM along the Bay of Bengal region. The seasonal trend is also observed from the analysis, where maximum sediment concentration is observed during the post-monsoon period for the entire coastal region. Cloud cover have prevented the estimation of TSM during the monsoon period. The changes in the sediment input can significantly affect the coastal environment, like reduced sediment transport into the coastal region may increase the coastal erosion rate, reduction in nutrient influx.

Keywords: MODIS, Total suspended matter, Google Earth Engine, Long-term change, Coastal region

Deployment and performance validation of upgraded Indian Tsunami Buoy System

[ABS-02-0296]

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The Indian Tsunami Buoy System (ITBS) developed and operated by the National Institute of Ocean Technology (NIOT) is used for monitoring the water level changes in deep oceans during the propagation of a tsunami wave. The water level data serve as one of the critical inputs to the Indian Tsunami Early Warning System (ITEWS) for confirming a tsunami, estimating its travel time to shore, and assessing possible impacts on the coastline of the Indian Ocean rim countries during a tsunamigenic earthquake. The first ITBS was deployed in 2007 which was conceived following the deadly Tsunami of 2004. The ITBS comprises a network of four moored surface buoys (MSB); three systems in the Bay of Bengal (BoB) and one system in the Arabian Sea. The MSB transmits the received data to the satellite terminal, which, in turn, transmits it to the NIOT and Indian National Center for Ocean Information Services (INCOIS) data analysis center. Presently all the ITBS is upgraded with the additional features such as rugged and low power electronics, increased battery capacity, global data compatibility and high accuracy pressure transducer etc. Also added more trouble shooting parameters such as enhanced acoustic signal strength of surface acoustic modem and increased float size of Bottom Pressure Recorder (BPR) which helped for better acoustic communication, faster and easy recovery of the BPR unit. The endurance of the upgraded system has increased to 2 years from 1 year due to increased battery capacity and hence reduced the no of operational visit and related expenses. The upgraded systems deployed in all the four locations performing satisfactory till date.

Keywords: Tsunami, ITBS, ITEWS, NIOT, INCOIS

Studying the biogeochemical response of the northern Indian Ocean to tropical cyclones using Argo profiling floats and satellite derived datasets

[ABS-02-0491]

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Tropical cyclones (TCs) are synoptic-scale (100 to 600 km of horizontal ranges) warm core cyclonically rotating wind systems formed in a weakly sheared troposphere over warm tropical oceans. The northern Indian Ocean (NIO) hosts only about 7-10% of the global TCs annually and yet more than 80% of global fatalities due to coastal flooding during TCs occur in this region. When a TC passes, it significantly modulates the state of the upper ocean. Along with the changes in the physical state; which include cooling at the surface, changes in salinity stratification, associated response of ocean currents, etc., biological responses form an integral part of the alterations in the ocean structure induced by TCs. Studying these responses prove to be difficult because of the obvious hazards associated with obtaining real-time observation during TCs. Early studies of TC genesis, their intensification, and the subsequent interactions through feedback with the ocean and the atmosphere were undertaken by researchers using a few rarely available observational datasets during fortuitous storm encounters. Since observational datasets proved to be so helpful in providing information about TCs, wartime reconnaissance started to be regularly employed to facilitate TC forecasts. Because the lifetime of a TC is away from land, satellite remote sensing provides an excellent opportunity for detecting and monitoring TC activities. The sensors onboard satellites provide measurements at a very high spatial resolution and high observing frequencies. Through a combination of enhanced IR image analysis and detection of cloud shapes at different stages of storm development information of TC structure, intensity, location, best track, rain band formation, shear etc. can be made. Data fusion from multi-satellite sensors aims to provide gap free global coverage of TC characteristics and track. Advanced algorithms like ARCHER is used worldwide to ascertain the best tracks of TCs along with the Dvorak technique which predicts TC intensity from the TC central position and wind- pressure relations. A very exhaustive dataset for global TCs documenting the track and characteristics of

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storms is available under the programme of International Best Track Archive for Climate Stewardship (IBTrACS). In the case of NIO, an electronic atlas of historic storm characteristics and track information is made available by IMD documenting storms from 1891 to the latest year (available at http://14.139.191.203/AboutEAtlas.aspx). Even though satellite remote sensing provides good spatial coverage, their visibility is restricted to the ocean surface layer. A reliable recourse to studying the ocean column response to TCs is buoy deployments. The biggest advantage of these buoys are that they provide subsurface visibility and datasets derived from these can provide valuable insights to the response of the vertical structure of the ocean to TCs. Free drifting Argo profiling floats measure both physical and biological variables of the ocean at pre-defined depths of the water column. In the NIO, biogeochemical Argos are majorly deployed and maintained by the Indian National Centre for Ocean Information Services (INCOIS). These Argos provide measurements of chlorophyll-a (chl-a) since 2012 till the present along with other ocean variables. Since Argos are free drifting, obtaining profiles near the track of TCs is only a matter of chance. Along with Argos, moorings like Research Moored Array for African-Asian-Australian Monsoon Analysis (RAMA) and Ocean Moored Network for northern Indian Ocean (OMNI) also provide information of the subsurface. The NIO has 4 RAMA each in the Arabian Sea (AS) and the Bay of Bengal (BoB) while there are 5 (7) OMNI moorings in the AS (BoB). In the equatorial and southern Indian Ocean there are 22 RAMA buoys in total but no OMNI. These moorings provide time-series and depth profiles of ocean parameters and the data is freely available in public domain except

Keywords: Biogeochemical Argo, Tropical Cyclones, northern Indian Ocean, Satellite remote sensing

Mapping species-specific potential fishing zones using historic Catch-logs on fishgram - a super app for marine fishing community

[ABS-02-0326]

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Captain Fresh

The urgent need for sustainable fishing practices and effective marine resource management has prompted the application of machine learning (ML) and statistical methods to identify species-specific Potential Fishing Zones (PFZs). Refer: Fishgram, a comprehensive super app for the marine fishing community, designed to improve fishing operations and promote sustainability. Fishgram features PFZ Maps powered by INCOIS, enabling fishermen and boat owners to search for fishing hotspots. The app also offers navigation features like bathymetry depth, weather features such as ocean state forecasts, and catch log capabilities for recording catch details. Our proposed framework utilizes ML algorithms and statistical models to analyze diverse data sources, including satellite imagery and oceanographic data such as ocean surface temperature, wind patterns, atmospheric pressure, surface ocean current patterns. Historical catch logs are also integrated into the analysis sourced from fishgram. By combining these datasets, the framework predicts the occurrence of specific species and identifies targeted areas that exhibit similar geophysical parameters. The workflow utilizes a Multimodal Machine Learning approach, to layer the embeddings from each data source to identify species specific PFZ mappings. To begin with, the paper will focus on a few of the high value marine species such as Cephalopods (Squids, cuttlefish, octopus), Tuna, Indian Mackerel, Groupers to analyze for their catch locations and migratory patterns. Our stakeholders include West Coast purse seine fishing Welfare Association and Karanja Fishering Cooperative Society Limited who are invested in giving feedback on the PFZ service and validating the catch logs and catch quantity. This framework allows for the redefinition of PFZs with potential species tagging, aiding fishermen and businesses in targeting high-value species and tracking catch logs. By leveraging ML algorithms and ocean observation, Fishgram contributes to sustainable marine resource management and the preservation of our oceans' biodiversity.

Keywords: sustainability,PFZ,INCOIS,fishgram,MachineLearning,Tuna,Groupers,cephalopods,Indian Mackerel

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Monitoring river plumes of goa using a novel algorithm for estimating chromophoric dissolved organic matter in estuarine and coastal Waters

[ABS-02-0252]

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The chromophoric dissolved organic matter (CDOM) in estuarine and coastal waters originates either from land or in-situ decaying of organic matter. Improvements in accuracy and synoptic coverage of optical remote sensing in these waters hold immense potential to monitor ecological health and sustain fisheries. In estuarine and coastal waters, resolving bio-optical complexity using inverse modeling of remote sensing reflectance (Rrs) has been challenging. This study introduces a novel semi-analytical approach to delineate CDOM absorption and tests a three-wavelength algorithm using different optical remote sensors. The developed algorithm has a form, $Rrs(\lambda) \propto bb(\lambda)/(a(\lambda)+bb(\lambda))$, where $a(\lambda)$ and $bb(\lambda)$ are the total absorption and backscattering coefficients of bio-optical constituents, and are additive in nature, respectively. An index of form, $(1/Rrs(\lambda 1)-Rrs(\lambda 2)*Rrs(\lambda 3))$ represented Rrs at three wavelengths ($\lambda 1$, $\lambda 2$, $\lambda 3$) removing the absorption by chlorophyll-a, suspended matter and water molecules, and accounting for particulate backscattering, was regressed with a subset of in-situ CDOM absorption coefficient at 440 nm (acdom(440)). The in-situ subset included regional waters and measurements from different bio-optically complex waters of World Ocean. Further, a distinct subset of in-situ data was used to validate the algorithm and applied to different optical remote sensors. In terms of Rrs, the acdom(440) retrieval was formulated as $0.01318x^2+0.08082x+0.04186$, wherein x represents the index. The validation of the algorithm with an in-situ subset resulted in $r^2 = 0.61$ and RMSE = 0.1085 for a total of 677 data points. Additionally, the validation with satellite match-up showed a strong correlation coefficient, $r^2 = 0.8$, and RMSE = 0.208, for 17 data points. The developed algorithm was applied to Mandovi and Zuari estuaries in Goa to study the diffusion of river plumes in the post-monsoon season. The riverine discharge controlled plumes were witnessed in the

region with middle and lower stretches of estuaries with high acdom(440) values (0.6-0.9 m^-1) in October. The acdom(440) values decreased to 0.25-0.4 m^-1 in January, with the spatial extent of the plume limited to the upper stretches of estuaries. This seasonal pattern was validated with the in-situ data to understand the algorithm's applicability in bio-optically complex waters of the region.

Keywords: Chromophoric Dissolved Organic Matter, Bio-optics, River Plumes

Assimilation of Blended Sea Surface winds for simulating Tropical cyclones over the Indian Ocean

[ABS-02-0070]

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Sea surface wind assimilation plays a pivotal role in the simulation of cyclone features. All the global leading operational Numerical Weather Prediction (NWP) centres assimilate space-based sea surface winds from various active instruments. Currently there are two scatterometer instruments, Advanced Scatterometers (ASCAT) onboard MetOp-B and MetOp-C, with nearly half an hour difference in the equator crossing time. NCMRWF receives ASCAT data over the Indian Ocean during 0600 and 1800 UTC assimilation cycles. This limits the updates of sea surface winds assimilation during 0000 and 1200 UTC assimilation cycles, based on which NCMRWF generates the long forecasts. National Oceanic and Atmospheric Administration (NOAA) has released a 6-hourly interval blended sea surface wind product with global coverage. The NOAA National Centers for Environmental Information (NCEI) Blended Sea Winds (NBS) product has been generated by blending multiple sources of satellite data including scatterometers, and microwave radiometers/imagers. In addition to these instruments, the NBS product also uses L-band (1.42 GHz) instrument on the Soil Moisture Active and Passive (SMAP) satellite and the AMSR-2 all-weather channel (6.9 GHz), which can provide the maximum winds up to 65 m/s, compared to the scatterometer limit of 25-30 m/s. Since the NBS uses many sources of data, and hence this product is not available in near-real time, and this limits its operational usage. However, these blended winds can be used in the assimilation in a lagged mode. In this study, these blended winds are used in the NCMRWF Unified Model (NCUM) assimilation and forecast system to simulate characteristics of two back-to-back cyclones formed over the Indian Ocean, Mocha, over the Northern Hemisphere and Fabien, over the Southern Hemisphere during May 2023. We expect a better simulation of cyclone features in terms of central pressure, track, maximum sustained wind, etc., due to the assimilation of the six hourly NBS. We also analyzed whether these cyclones have any impact on modulating the Indian southwest monsoon onset.

Keywords: Data Assimilation,Sea surface winds ,Tropical cyclone

Wave characteristics observed by HF radar sites along the east coast of India during the passage of the extremely severe cyclonic storm MOCHA

[ABS-02-0379]

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The National Institute of Ocean Technology (NIOT) installed and maintains the Indian Coastal Ocean Radar Network (ICORN). Ten numbers of High-Frequency radar (HFR) included in this ICORN spread over the Indian coast, including the Andaman Islands. The waves measured from various HF radar sites (4.4MHz) along the east coast of India during the extremely severe cyclonic storm (ESCS) MOCHA over the Bay of Bengal (BoB) from 09th-15th May 2023 are analyzed. Depression was formed in Southeast BoB on 09, May-2023 at 17:30 IST; it moved north-northwest and intensified into a Cyclonic storm on 11th, May-2023. It crossed north Myanmar-southeast Bangladesh coasts between Kyaukpyu (Myanmar) and Cox's Bazar (Bangladesh) close to the north of Sittwe (Myanmar) (20.3°N 92.8°E) as an ESCS with maximum sustained wind speed (MSW) of 180-190 kmph gusting to 210 kmph during 1230 to 1430 hours IST of 14, May-2023. Ocean wave parameters are derived from the second-order peak adjacent to the first-order peak in the frequency spectra by the inversion of a two-dimensional nonlinear integral equation. Fitting a model of ocean wave spectrum to radar data gives estimates of wave height, period and direction. The first-order peaks are typically two orders of magnitude higher than the surrounding continuum, from which well-defined nulls separate them. During the Depression and Deep Depression, the cyclone track from the Port Blair HF radar site is away about 500km; the measured wave height varied from 9th - 10th May 2023 is 0.73m to 2.4m. From the start to landfall, the Wave heights were measured by the HF radar remote sites located along the east coast of India, including Andaman Island (Cuddalore, Machilipatnam and Puri HF radar remote sites are located away from cyclone track about 900km, 800km and 550km, respectively), analyzed and presented in this manuscript. Compared the maximum wave height observed by HF radar during VSCS Phailin and Hudhud with the Mocha cyclone.

Keywords: Wave, HF radar, Cyclone, MOCHA

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Moored Buoy Static Sea-Swell separation frequency year round Conformity Check - A case study in the swell dominant central Arabian Sea

[ABS-02-0396]

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Day to day marine operations are governed by wave conditions and the prevailing sea state at the location of interest. Operational models that issue wave forecasts need to be validated with measurements for proving their performance and applicability. The assimilation of observations into models improves the forecasts, especially during cyclones and extreme events. Swells from far field reaching a location have a long memory in the assimilation. Hence, there is a need to separate the local wind waves and the swells from distant storms, from the combined significant wave height. The Arabian Sea is characterized by swell waves. The predominance of South West monsoonal waves is also evident in the Arabian sea. The combination of pre-existing swells with local wind seas, defines the combined wave conditions in the Arabian Sea. The present study focuses on separating the local wind seas and swells at a location in the central Arabian Sea using a year round moored buoy measurements of National Institute of Ocean Technology, covering pre-monsoon, monsoon and post-monsoon seasons. Buoy algorithm in NIOT- moored buoys assume a constant sea-swell separation frequency at 10 s (0.1 Hz), whereas, in nature, the separation frequency for real waves varies for different sea conditions during different seasons. The wave spectra in Indian waters during a year vary from single peaked sea or swell spectrum to a double peaked sea dominant or swell dominant spectra. During cyclones, rapid variation is exhibited in sea-swell compositions. The deviation of the actual separation frequency during cyclones leads to changes in the sea and swell energy content. The discrepancies if any, with reference to 0.1 Hz separation frequency, during the low wind conditions associated with swells from distant storms are also studied. The percentage conformity during different seasons is brought out. This study helps in understanding the conformity of the assumption of the constant moored buoy sea-

swell separation frequency and thereby improves the confidence of the validation of wave models with in-situ observations. Accurate partition of the wind seas and swells improves the data assimilative capacity of individual components, wherein the swells exhibit longer memory than the wind seas.

Keywords: Moored buoy, Arabian Sea, wind seas, swells, separation frequency

Land breeze system in the Bay of Bengal; Seasonality and impact on near-surface current and air-sea interactions.

[ABS-02-0214]

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The land-sea breeze system is a mesoscale phenomenon that occurs due to differential heating between the land and ocean surfaces that evolves over the course of a day and is a vital component of the climate system at least in coastal regions. The impact of the Land Breeze System (LBS) on the offshore region remains unexplored because of the limited availability of in-situ data. In this study, the seasonality of the LBS in the Bay of Bengal (BoB) is examined using hourly moored buoy data (OMNI), coastal radar data, atmospheric reanalysis data (ERA-5), and 6-hourly satellite-based Cross-Calibrated Multi-Platform (CCMP) wind velocity data. The seasonality of LBS over the entire BoB is examined and the seasonally evolving large-scale winds in the southwestern BoB show an annual variability with maximum geographical coverage and amplitude (2 m s−1) during summer and minimum during winter. This significant modulation of wind speed due to the land breeze signal imparts a well-defined diurnal variability in latent heat flux (LHF) and near-surface current variability. LHF shows well-defined diurnal variability in response to diurnal LBS wind speed variability, with a diurnal range of 35 Wm−2. The near-surface current field also responds to the diurnal wind speed variations, with an eastward current observed between 1000¿1800 IST, a westward current between 1800¿0800 IST, and a diurnal range of 12 cm s−1.

Keywords: Bay of Bengal, air-sea interaction, sub-daily variability, land-sea breeze system

Role of Ocean parameters in modulating tropical cyclone intensity and structure using satellite and model data.

[ABS-02-0429]

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The tropical cyclones (TCs) are one of the most disastrous natural hazards that badly impact the coastal regions. North Indian Ocean (NIO) shares only 7% of the global TCs. However, Indian coasts are highly affected by TCs due to low bathymetry, funnel shape coastal boundary and high density of population in the coastal areas. Bay of Bengal (BoB) is more vulnerable as compared to Arabian Sea (AS) with 4 times more cyclones forming over BoB. The timely prediction of TCs genesis, track and intensity helps in disseminating warnings and preparedness to overcome the losses. TCs track and intensity predictions are provided with reasonable accuracy using Numerical and statistical models. However, there is a need of more understanding of its internal structural dynamics to understand its characteristics like intensity changes, and rainfall asymmetries. The in-situ observations from buoys are very limited and coastal radars provide data only when the TCs are within the range. Thus, to understand the rainfall characteristics within the cyclone, the satellites observations are most useful. In the present study we aimed to analyse the rainfall asymmetries of TCs and study its association with TC intensity changes and movement over the BoB region. Based on the spatial distribution of cyclonic rainfall, we identified critical ocean sectors contributing to the intensification of the cyclone. We have considered TCs from 2011 to 2021 to find out the threshold of ocean parameters such as SST, air sea temperature gradient, sea level anomaly (SLA), net heat flux crucial for the sustenance of the cyclone. The analysis is based on the daily mean values of these parameters over a period of 10 days preceding the formation of cyclones. The spatial average is computed within a 10-degree latitude and longitude box centered about the location of the cyclone. The analysis is carried out for TCs in various stages, including depression, deep depression, cyclone, severe cyclone, very severe cyclone, and extremely severe cyclone. Final objective of the study is to compute an index based on the ocean parameters which can be used as a whistle blower of TC intensification.

Keywords: Cyclone, Satellite Data, Bay of Bengal

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Light absorption characteristics of phytoplankton and associated parameters in the northeastern Arabian Sea.

[ABS-02-0333]

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Attempts exploring the bio-optical properties, which play a crucial role in influencing the underwater light field and phytoplankton community structure, have been extremely sparse in the Arabian Sea to date, leaving the Carbon cycle of the region needing to be clarified. Considering these insufficiencies, we present the spatial variability of the surface bio-optical constituents (i.e., Chlorophyll a (Chl-a), light absorption by phytoplankton (aph(443)), detritus (ad(443)), coloured dissolved organic matter (aCDOM(443)), and associated hydrographic parameters in two transects (T1&T2) during February 2019 in the northeastern Arabian Sea (NEAS) during winter. Physical properties showed euphotic depth (Zeu) is below mixed layer depth (MLD) and thermocline, which caused high surface productivity in both the transects. Moreover, the T2 transect showed high coastal to offshore bio-optical variability than T1. aph(443) and a*ph(443) showed a decreasing trend from nearshore to offshore, whereas aCDOM(443) and ad(443) showed an increase in trend at T2, suggesting that degradation of detritus matter by photochemical and bacterial and producing CDOM. The decrease in a*ph(443) suggests pigment package increasing from coastal to offshore at T2 than T1. Phytoplankton pigment composition distinguished the phytoplankton size classes well in this region; it showed pico abundance in coastal waters and nano and micro phytoplankton in offshore waters. Hirata et al. (2008) size class global absorption model is also well-fitted in this region. Relative contributions of aph(443)), ad(443), and aCDOM(443) to the total absorption (at) showed a decrease in phytoplankton contribution and an increasing contribution of aCDOM(443) and ad. A positive relationship between aCDOM(443) with Chl-a and a negative association with slope (S300-500) suggested autochthonous production of CDOM. This study provides baseline data for bio-optical observations and would facilitate the detection of phytoplankton size classes and carbon dynamics using space-borne sensors.

Keywords: Bio-optics, CDOM absorption, phytoplankton absorption.

Quantifying the wave effects on momentum flux in low to medium wind regime in the Bay of Bengal

[ABS-02-0228]

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Accurate estimates of momentum exchange between the ocean and atmosphere play a crucial role in understanding and modeling air-sea interactions. This study uses 16-month-long eddy covariance data collected from a moored buoy in the northern Bay of Bengal to investigate the momentum transfer under light to moderate winds under varying wave conditions. Previous studies have demonstrated significant variability in drag coefficient estimates, especially at low wind speeds, indicating the influence of swells and rapidly changing winds. Therefore, this study specifically examines the impact of fast-traveling ocean swells and their direction on momentum transfer, as these swells have been observed to affect weak wind dynamics at sea profoundly. Additionally, the commonly used bulk formulations based on the Monin-Obukhov similarity theory are thoroughly evaluated. By accounting for the effects of swells and other relevant factors, this research seeks to improve the estimation of the drag coefficient over the sea and advance bulk formulations to capture these intricate interactions accurately. Ultimately, the outcomes of this study will contribute to a deeper understanding of air-sea interactions and their implications for improving weather and climate modeling.

Keywords: Eddy covariance,Air-sea fluxes,WindStress,WindWaves,Swell

Comparison of the rate of evaporation from satellite and buoy data: A mathematical analysis

[ABS-02-0099]

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This study investigates the evaporation rates in the Arabian Sea (AS), which has one of the highest rates of evaporation in the world after the Red Sea. The objective of this study is to compare the rate of evaporation obtained from satellite data and buoy data in the AS. Satellites provide a remote sensing tool to estimate the rate of evaporation over large areas, while buoys provide in-situ measurements of evaporation at a specific location. By comparing the evaporation rates obtained from both sources, it may help to identify any discrepancies or biases in the data obtained from each source. National Institute of Ocean Technology (NIOT) has been deploying Ocean Moored buoy Network for northern Indian Ocean (OMNI) buoy systems to gather data on meteorological and subsurface conditions at depths of up to 500 m. Evaporation from the surface of the AS is calculated using buoy data utilizing mathematical calculations that entail measuring a number of climatic conditions, including air temperature, relative humidity, wind speed, sea surface temperature (SST), etc. These were compared to the satellite data, and it was found that the average yearly evaporation error for the Dalton's equation, with coefficient K=0.10137, was just 2.54 %. The buoy data used for comparison was collected from AS over a period of 12 months from the AD06 buoy (180N, 670E) in the year 2013. The study also observed an average annual evaporation of more than 5 mm/day in the northern regions of the AS. Four buoys were then placed in both the Arabian Sea (AD06 and AD09) and the Bay of Bengal (BoB) (BD09 and BD14) in the year 2014, and the rate of evaporation for each buoy was determined using Dalton's formula. Evaporation trend varies between AS and BoB depending on buoy location and climate/ocean conditions. By combining the two types of data, researchers can get a more accurate picture of evaporation rates over a larger area, taking into account the variability in environmental conditions that can affect evaporation. This can be especially useful in regions where there are few or no buoys or other measurement tools available.

Keywords: Evaporation rate, Dalton's law, Arabian Sea, Buoy, Meteorology

Intra-tidal variability in hyperspectral remote sensing reflectance associated with changing bio-optical constituents in a tropical estuarine ecosystem

[ABS-02-0182]

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The study aims to understand the variability of in-situ measured hyperspectral remote sensing reflectance (R_rs (λ)) simultaneous to prevailing bio-optical constituents at intra-tidal timescales. Spatial and temporal field surveys were carried out in Zuari estuary, Goa, during the post-Indian Summer Monsoon season on 12th October and 26th November 2019, respectively. The water sampling analysis to generate absorption coefficients of bio-optical constituents, and radiometer measurements to acquire upwelling and downwelling irradiances were conducted at flood and ebb phases of tide. These observations (15.41273°N; 73.8814°E) were carried out during the spring tide to understand maximum variation in the optical nature of water, while the spatial survey was during neap. From temporal analysis, it was observed that R_rs peak at 680 nm during the flood phase shifted to ≈580 nm during the ebb phase. A similar shift in R_rs peak from longer wavelengths (580 nm, flood phase) to shorter (500 nm, ebb phase) was also observed during the spatial survey. However, the magnitude of R_rs peak at shorter wavelengths during the temporal survey (spring tide) was several times higher than the spatial observations. This shift in R_rs peak was associated with the intra-tidal variations in the concentrations of bio-optical constituents. The chlorophyll-a (Chl-a) concentrations decreased drastically during the ebb phase of neap (52.3 μg L-1 to 2.8 μg L-1) and spring tide (30.2 μg L-1 to 14.4 μg L-1). In contrast, the total suspended matter (TSM) concentration increased from 6.4 to 40.2 mg L-1 (neap) and 15.0 to 242.0 mg L-1 (spring). The absorption coefficient of chromophoric dissolved organic matter (CDOM) at 440 nm (a_CDOM^440) also increased from 0.3 m-1 to 0.6 m-1 from flood to ebb phase of spring and neap tides, respectively. Further, the absorption budget analysis revealed that the stronger

absorption of the shorter wavelengths during the ebb phase might be associated with the shift in R_rs peak due to manifold increase in a_CDOM^440 values. The outcome of this study emphasizes the significant changes in ocean colour at intra-tidal timescales that require to be resolved in optical remote sensing to monitor ecological health of optically complex waters.

Keywords: bio-optical complexity, R_rs variability, ocean colour,intra-tidal,estuarine ecosystem

Observed currents off the coast of Rameswaram Island

[ABS-02-0378]

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We present the observed current data obtained from Recording Current Meters deployed in the periphery of Rameswaram island(Tamil Nadu, India) during 2010-2011. The island is sandwiched between Palk Bay(PB) and Gulf of Mannar(GoM) which lie to the north and south respectively. The ocean of this region is ecologically important as it harbors diverse corals and many sensitive fauna. Data used in this manuscript were part of Sethusamudram Shipping Channel Project undertaken by the Government of India. Observations of raw currents indicate that there is seasonally reversing current, distinctly visible at location near to channels, with strong northeastward(southward) current seen at Pamban Pass in spring to summer monsoon(autumn to winter monsoon) months. A Northward(Southward) transport of 586.89 m3/s (818.55 m3/s) during summer (winter) monsoon at Pamban Pass is seen where annual mean current is ~27 cm/s. However, the annual net transport is northward. The effect of wind on current is evident from the correlation of reanalysis wind data with observed current. This leads to 6 hour resampled cross-shore (along-shore) currents at Adam's Bridge and Pamban Pass to have a correlation value of 0.67(-0.53) significant at 1% level. Residual currents are similar to the raw currents in sense of seasonality and current strength. A local scale circulation is observed around the island during summer monsoon. Tidal analysis reveals that the M2 tidal constituent is strong at Adam's Bridge and PB, but we also notice S2 (at Pamban Pass) or K1 (at GoM) emerging as the strongest tidal constituent. We present evidence that a minor shift in deployment location can lead to dramatic shifts in raw current for shallow water locations. Inertial currents were found to be of negligible strength compared to tidal currents, possibly due to stronger bottom friction. The bathymetry of this region plays a major role in determining the strength and direction of raw current as well as the tidal and residual currents.

Keywords: Rameswaram island, Recording current meter, TASK,raw and residual currents,tidal and inertial currents,tidal constituents

Wave and tide analysis near the southern Arabian Sea from in-situ measurement
[ABS-02-0356]

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The ocean is dynamic and influenced by the physical characteristics of the sea and external forces through anthropogenic and natural events. Water's horizontal and vertical motions in ocean bodies generate tides, waves, and currents. Automated instruments were used for in-situ tide and wave measurements near the southern Arabian Sea. A pressure-based tide gauge was installed for tide measurement, and a GPS-based directional buoy was deployed near 20m of water depth for wave measurement. The harmonic analysis was carried out on observed tide data using Matlabt_tide for semi-major and diurnal constituents (M2, S2, O1, and K1). The estimated tidal range from the observation is ~ 1.1m, and the mean sea level is 0.55m. The major constituents' M2, S2, O1, and K1 amplitudes are 0.174, 0.098, 0.067, and 0.147, respectively. Similarly, the 2048 samples of wave data have been analysed in time series and frequency domains using FFT to estimate wave parameters for three months (January to March). The significant wave height ranges from 0.41 to 1.40 m, and the wave period ranges from 3.54 to 9.09 s. During the measured duration, the predominant wave direction from S to SSW (196°). Recently, the intensity of high wave activity and tidal surges has increased, which may be due to climate change. Hence, long-term measurement and analysis of oceanographic parameters will help coastal scientists, engineers, fisheries, marines, ports, and disaster management handle the contingency plan efficiently.

Keywords: Wave, Tide, harmonic, ports, constituents

Observational evidence of salt finger in the diurnal thermocline
[ABS-02-0131]

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In general, the ocean surface boundary layer region is not conducive to double diffusion due to the intense turbulent mixing. However, observations of vertical microstructure profiles in the northeastern Arabian Sea in May 2019 suggest the formation of salt fingers in the diurnal thermocline (DT) region during the daytime. In the DT layer, conditions are favorable for salt fingering: Turner angle values are between 50 and 55° with both temperature and salinity decreasing with depth; shear-driven mixing is weak with a turbulent Reynolds number of about 30. The presence of staircase-like structures with step sizes greater than the Ozmidov length and a dissipation ratio greater than the mixing coefficient confirms the presence of salt fingering in the DT. The unusual daytime salinity maximum in the mixed layer that supports salt fingering is primarily due to a daytime reduction in vertical entrainment of fresh water along with minor contributions from evaporation and horizontal advection and a significant contribution from detrainment processes.

Keywords: Diapycnal mixing,doublediffusion,indianocean,turbulence

Evaluation of Atmospheric corrections for MODIS-Aqua images over coastal waters of Bay of Bengal

[ABS-02-0164]

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Ocean colour remote sensing plays a vital by providing valuable insights, large and long term uninterrupted applications into mechanisms associated with climate change, ocean productivity, biogeochemical cycles by understanding the spectral response of substances to the ambient light field. The information regarding ocean surface product viz., Chlorophyll-a (Chl-a) obtained from ocean colour sensors involve atmospheric correction and bio-optical algorithms. The atmospheric correction is more critical than bio-optical algorithms, as ~ 80- 85% of the signal received by the sensors comes from the atmosphere. Therefore, retrieving the desired ocean colour signal for the correct estimation of the in-water constituents by removing the atmospheric contribution is realized as a big challenge especially in coastal waters. The process of removal of atmospheric impediments from the satellite imagery called atmospheric correction. The present study evaluated the performance of three atmospheric correction algorithms such as (1) the standard NIR correction algorithm of NASA, (2) NIR- SWIR combined approach, (3) The Management Unit of the North Seas Mathematical Models (MUMM) for the coastal waters of Bay of Bengal. The atmospherically corrected products of MODIS-Aqua remote sensing reflectance (Rrs), Chl-a and Aerosol Optical Depth (AOD), were compared with the in-situ measurements of Rrs obtained using a Hyperspectral Underwater Radiometer, as well as in-situ measurements of Chl-a and AOD obtained using a sunphotometer. The result indicated that the NIR-SWIR correction approach was the most appropriate for the region with relatively good retrieval of atmospheric products, improved retrieval of Rrs and improved retrieval of Chl-a. The poorest Chl-a retrievals were achieved using MUMM method. The NIR-SWIR correction approach also proved its efficacy for the retrieval of AOD. However, MUMM was least accurate for the retrieval of AOD. Hence NIR-SWIR combined method can be further tested in other coastal regions of the Indian Ocean

Keywords: Bay of Bengal, Chlorophyll,Atmospheric correction,Ocean colourremote sensing

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Double Diffusion in the Arabian Sea during Winter and Spring

[ABS-02-0111]

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Microstructure measurements from two cruises conducted in the winter and spring of 2019 revealed the significance of double-diffusion processes for small-scale mixing in the upper 400 m of the open-ocean region of the eastern Arabian Sea (EAS) beneath the mixed layer. The data indicated that shear-driven mixing rates are weak, contributing diapycnal diffusivity (Kρ) of not more than 5.4 × 10−6 m2 s−1 in the EAS.In contrast, double diffusion signatures were prominent, with the water column favourable for salt fingers in 70% of the region and favourable for diffusive convection in 2%-3% of the region, respectively. Well-defined thermohaline staircases were present in all the profiles in these regions that occupied 20% of the water column.Strong diffusive convection favorable regime occurred in ~45% of data in the barrier layer region of the southern EAS (SEAS). it was found that the Radko and Smith salt fingering scheme and the Kelley diffusive convection scheme most closely match the observations. The estimates based on flux law show that the combination of downward heat flux of approximately −3 W m−2 associated with salt fingering in the thermocline region of the EAS and the upward heat flux of ~5 W m−2 due to diffusive convection in the barrier layer region of the SEAS cools the thermocline.

Keywords: Diapycnal mixing,IdianOcean,Turbulence

Atmospheric correction and generation of ocean colour products from EOS-06 Ocean Colour Monitor (OCM3)

[ABS-02-0203]

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Ocean colour remote sensing has proven to be a powerful tool to study and monitor the marine biogeochemical properties. Ocean colour sensors aim to derive the spectral distribution of visible solar radiation backscattered/reflected from above/below the ocean surface and passing through the sea-air interface. The measured Top of the Atmosphere (TOA) radiance is mainly influenced by the scattering of light by air molecules and aerosols in the atmosphere and accurate modelling and removal of these atmospheric contributions are essential. Additionally, surface effects such as whitecaps and sun glint, which is the sun's specular reflection into the sensor's field of view, need to be estimated and eliminated. Finally, corrections are needed to account for the attenuation caused by absorbing atmospheric gases and the scattering losses associated with the transmission of water-leaving radiance through the atmosphere. This process of correcting for atmospheric effects to retrieve water-leaving radiance from the TOA radiance is commonly known as atmospheric correction. This water-leaving radiance is used for estimation of chlorophyll-a concentration and for the retrieval of other biogeochemical parameters, such as suspended particulate matter, coloured dissolved organic matter. The EOS-06 (Earth Observation Satellite-06), also known as Oceansat-3, is a satellite mission developed by the Indian Space Research Organisation (ISRO) specifically designed for oceanographic and coastal studies. The mission includes the Ocean Colour Monitor 3 (OCM3) instrument, the third generation ocean colour sensor of ISRO, which is dedicated to monitor the optical properties of the Earth's oceans. This is a global mission with a native resolution of 360m for the Indian Ocean region and 1Km for global ocean coverage with 2-day receptivity. It measures the electromagnetic radiation reflected or scattered by the Earth's oceans in 13 spectral bands covering the Visible and Near Infrared (VNIR) Region of the electromagnetic spectrum. The OCM3 data is corrected for the atmospheric effects and important ocean colour products are generated using the standard algorithms. These retrieved products are compared with the standard products from other contemporary ocean colour sensors such MODIS, VIIRS, OLCI etc. The retrieved products are also compared with available in situ measurements or the data from Bio-Argos.

Keywords: EOS06 OCM3, Ocean Colour, Atmospheric Correction, Water Leaving Radiance, Chlorophyll-a Concentration

Sub-Theme-03

Ocean Modelling and Data Assimilation

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Improved reanalysis using global ocean data assimilation system (GODAS)

[ABS-03-0394]

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INCOIS is providing near real-time global analysis/reanalysis with the Global Ocean Data Assimilation System (GODAS) adopted from NOAA/NCEP since 2013. It provides the necessary initial conditions to initialize CFSv2 coupled model, which is used for the seasonal prediction of Indian Summer Monsoon Rainfall. This system uses state of the art ocean general circulation model based on an older version of MOM (version p0d) released in 2004 (version-4p0d) and 3DVar assimilation techniques to assimilate subsurface temperature and salinity observations. Temperature and salinity profiles from all in-situ observations over the global ocean are assimilated to produce the best analysis products in near real time by using NCMRWF operational atmospheric forcing. A more recent improved version MOM4p1 and MOM5 was released in 2009 and 2012 and many operational and research centers around the world are using these versions. We upgraded the physical model in GODAS from MOM4p0d (2004) to MOM4p1 (2009) and further to MOM5 (2012). In this study, we will show the results from upgraded ocean reanalysis by using the Global Ocean Data Assimilation System (GODAS) with the Modular Ocean Model MOM4p1 and MOM5 as a physical model and 3DVar as the data assimilation method. These new upgraded analysis/reanalysis shows significant improvement in sea surface temperature (SST), sea surface current, subsurface temperature, salinity, currents, and thermocline depth when assimilating observed temperature and salinity compared to present operational GODAS analysis/reanalysis. An assimilation scheme has also been implemented to assimilate along-track sea level anomaly data in this new GODAS, further improving ocean reanalysis.

Keywords: Global Ocean Data Assimilation, Indian Ocean

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Assimilation of satellite based directional wave spectra for the improved wave predictions in the Indian Ocean

[ABS-03-0074]

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Observations of Ocean wave directional spectra and associated wave parameters are made using Surface Wave Investigation and Monitoring (SWIM) instrument on-board China France Oceanography SATellite (CFOSAT). SWIM illuminates the Earth's surface at six incidence angles ranging from 0 to 10°. The nadir beam observations provide information on wind speed and Significant Wave Height (SWH) similar to a classical altimeter, whereas the 6, 8 and 10 degree beams provide the wave spectra information. Each SWIM spectrum represents an area of about ±35 km along-track and 90 km on each side of the nadir. The spectrum is discretized over 32 wave numbers corresponding to the wavelength 22¿500 m and 12 directions at every 15°, with a 180° ambiguity. In the present work, we have attempted to assimilate the SWIM observed wave spectra into a third generation spectral wave model, WAVEWATCH III (WW3). Here, the model spectrum is discretized with 29 frequencies (0.035-0.5047 Hz) and 36 directions with 10° increment. Since it is not practical to assimilate the entire spectral components, the SWIM and model spectra are initially partitioned into limited number of distinct wave systems. Each partition is characterized by three integral wave parameters: SWH, Mean Wave Direction (MWD) and mean frequency. Partitions from the model are matched with those from SWIM by minimizing the distance between their mean wave numbers. An optimal interpolation technique is applied to the three mean parameters for generating the analysis mean fields, which are then used to scale the model background spectra. Finally, all the analysis spectra corresponding to different partitions are superimposed to reconstruct the complete analysis wave spectrum. This algorithm is implemented for the Indian Ocean domain of the WW3 model, which has a spatial resolution of 0.5°x0.5°. The experiments are performed for the month of November, 2020. Generated analysis fields for the first

wave partition exhibit differences of up to ~1.6 m for SWH, ~10° for MWD and ~0.15 m^-1 for mean wave number, in comparison to the model simulated background fields. Consequently, wave energy magnitude shows a difference of up to ~0.2 m^2/Hz/Deg with reference to the background wave spectra.

Keywords: Wave forecast, Data assimilation, Wave spectra, CFOSAT,WAVEWTCH III,Indian Ocean

Eddy Characteristics in North Indian Ocean: Improving model simulation with Data Assimilation

[ABS-03-0054]

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Mesoscale eddies play an important role in transporting heat, salt, and nutrient transport in the global ocean and altering the biogeochemical aspects by horizontal and vertical advection, yet they remain imperfectly represented in numerical ocean models. Previous studies had expected data assimilation, a technique which incorporates observations with the model simulation, to improve the estimates. This study assesses the influence of assimilating satellite altimeter sea surface height observations on the simulation of eddies in North Indian Ocean using LETKF assimilation system in a high resolution ROMS model. Results show that data assimilation significantly improves the detection of mesoscale eddies, increasing the number of eddies identified in the model by about 20% in the Bay of Bengal and 30% in the Arabian Sea. However, continued challenges remain in accurately representing eddy trajectories. Despite the inclusion of assimilation, the models still exhibit inefficiency in producing eddies with longer lifetimes. Coordinated efforts across observations, models, and assimilation, are essential to fully represent eddy evolution and motion in the challenging ocean environment. Progress in this area will lead to ocean models that can realistically reproduce the complex nature of eddy-mediated ocean transport.

Keywords: Eddies,Mesoscale Eddies,Arabian Sea,Bay of Bengal,Observation ,Model,Data Assimilation

Coastal storm surge and extreme sea level simulation using machine learning

[ABS-03-0096]

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There has been significant progress in understanding the mean sea level (MSL) change on both global and regional scales. Coastlines are also potentially prone to episodic high-intensity sea levels or extreme sea levels (ESLs) and coastal flooding; however, the understanding of these short-span (hours-days) events, driven by the combination of MSL, tides, storm surge, and waves is very limited. Only a few tide gauges of the global coastline have a long record of high frequency (minute-hours) sea and many tide gauges pose large data gaps. This limits a better understanding of storm surges along densely populated coastal belts. Historic storm surge estimation from the model-based studies and global reanalysis had considerable uncertainty due to the lack of proper validation and biases along the Indian Ocean coastlines. Here, we provided an AI/ML-based data-driven reconstruction (IOSSR) of high-frequency (hourly) storm surges along the Indian Ocean Coastline. Using the Long Short Term Memory (LSTM) neural network with predictors includes hourly MSLP gradient, 10m wind speed, and 2m air temperature, we reconstructed the high frequency (hourly) storm surge data along the TG locations in the Indian Ocean coastlines from 1979 to 2021. Validation of hourly surges and monthly extremes shows our data performing fairly well with a mean RMSE of less than 7 cm (<13% mean relative RMSE) and a mean correlation of 0.73. Simulation of extreme surges during cyclone events are outperforming presently available global surge reconstructions.

Keywords: Extreme sea level, storm surge,machine learning,coastal flooding,data reconstruction

Impact of bathymetry on Indian Ocean circulation in a regional model

[ABS-03-0163]

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The Regional Indian Ocean model based on Modular Ocean Model (MOM4p1) was used to understand the importance of realistic representation of bathymetry on Ocean General Circulation. The model has 1/4° resolution with Coordinated Ocean-Ice Reference Experiments (CORE-II) with two simulations only differing in the representation of bathymetry for the years 1992-2005. We also used recent reanalysis products from ORAS5 and SODA3 to compare the subsurface currents. We show that by the inclusion of realistic bathymetry, there is an improvement in the salinity, temperature, and currents, particularly near the coast. The salinity and temperature of the upper ocean are very close to the observed value near the coast. The bias in the salinity and temperature was reduced to half. The boundary currents and deep currents are very well simulated in the Bay of Bengal, which agrees with the observations as well as the past literature. The use of realistic bathymetry is found to be important to model ocean circulation and to properly simulate the ocean properties near the coast. We show the first time the circulation features at 1000 m and 2000 m depth in the Indian Ocean. We found intra-thermocline eddy at 100-200 m depth in the South Eastern Arabian Sea (SEAS). Further analyzing the current at different depths at SEAS showed that the improper representation of the ridge system results in the westward displacement of a subsurface cone-shaped eddy that reaches up to 1000 m depth.

Keywords: ocean model,bathymetry,boundary current,deep circulation,intra-thermocline eddy

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Characterizing internal tides in the Eastern Arabian Sea

[ABS-03-0175]

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Internal waves are ubiquitous throughout the world's oceans and are predominantly generated when barotropic tides flow over topography and disturb the stratification, thereby generating internal tides or internal waves of tidal frequency. Recent studies for the Bay of Bengal have suggested that the semidiurnal internal tides show the largest seasonal variability. However, internal tides' temporal variability, formation, and propagation mechanisms are not understood enough in the Arabian Sea. In the present study, hourly in-situ measurements of salinity, temperature, and currents collected at AD09 (8°N, 73°E) from January 2019 to December 2019 are utilised. The analysis shows that salinity has a major role in governing the near surface stratification, whereas temperature fluctuations govern the subsurface stratification at this location. In addition, the semidiurnal barotropic tides rotate in a clockwise direction, whereas the diurnal tides rotate anticlockwise. However, baroclinic semidiurnal tidal currents rotate anticlockwise at all depths, whereas diurnal tidal currents rotate both clockwise and anticlockwise at different depths. Based on the magnitude of the semi-major axis for K1, the strongest baroclinic currents are found near 100 m, dominated by rectilinear flow, whereas for M2, they are found at depths below 125 m. Further, rotary analysis shows both diurnal and semidiurnal frequency dominate in the Arabian Sea, as the constituents M2, S2, K1, and O1 form the most energetic part of the spectrum. In contrast, on the eastern part of the Indian peninsula, semidiurnal frequency dominates. Moreover, the utilization of the MITgcm (Massachusetts Institute of Technology General Circulation Model) is configured for the west coast of India. The model barotropic tide is validated by comparing the sea surface elevation anomaly with the tide-gauge data. The Indian monsoon system drives extraordinary seasonal variation in the Arabian Sea, and seasonal variations in stratification influence the internal tides in this basin. The study offers a significant understanding of the characteristics of internal tides in the eastern Arabian Sea and needs to be further investigated.

Keywords: Internal Tides,MITgcm Model,Rotary spectrum analysis

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Improvements in Regional Analysis of Indian OceaN (RAIN) with along-track altimeter sea-level anomaly (SLA) assimilation

[ABS-03-0207]

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RAIN (Regional Analysis of Indian OceaN) is a data assimilation system developed in INCOIS (Indian National Centre for Ocean Information Services) wherein ROMS (Regional Ocean Modeling System), which is an ocean general circulation model suited for regional basins and is used as a forecast model for Indian Ocean, is interfaced with the data assimilation scheme of Local Ensemble Transform Kalman Filter (LETKF). This system assimilates remote sensing data of sea-surface temperature (SST), in-situ temperature and salinity profiles to provide improved ocean state estimate. The speciality of this assimilation system is that it comprises ensembles that are initialized with different model coefficients like diffusion parameters and the ensemble members also respond to two different mixing schemes - K profile parameterization and Mellor-Yamada. This helps to maintain the ensemble's spread, which has always been a difficult challenge. The data assimilation system provides an improved initial condition to the operational ocean forecast model ROMS and better regional analysis. In order to enhance the improvements in the ocean state forecast, the assimilation system has been augmented to assimilate remote sensing data of sea-level anomaly (SLA). The assimilation system is modified to sequentially assimilate corrected SLA observations along with assimilation of in-situ temperature, salinity profiles and SST. We show that SLA assimilation improves the overall ocean state except at a few isolated locations. It improves the correlation with respect to observations and reduces the root-mean-squared error. We also show that SLA assimilation improves the estimation of currents.

Keywords: ROMS, Ocean data assimilation, LETKF, Indian Ocean

Evaluation of mixing schemes in the HYbrid Coordinate Ocean Model (HYCOM) in the tropical Indian Ocean

[ABS-03-0267]

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The performance of three different mixing schemes implemented in the HYbrid Coordinate Ocean Model (HYCOM), namely, K-Profile Parameterization (KPP), Goddard Institute of Space Sciences (GISS), and Mellor-Yamada (MY), is evaluated with respect to their simulation of upper ocean properties such as SST and mixed layer depth (MLD) in the tropical Indian Ocean. We analyzed interannual global HYCOM simulations without either data assimilation or SST relaxation for the recent period of 2012-2018. Our analysis shows that simulated SST is generally warmer by 1-2 °C than the observations and that there is little difference in SST between simulations by these different mixing schemes except in specific locations. The simulated MLD, irrespective of the choice of mixing scheme, in general, is deeper than observations in the tropical Indian Ocean, although this MLD bias varies with time and location depending on the mixing scheme choice. Furthermore, none of the mixing schemes analyzed consistently simulated the MLD with minimal error at all locations and for all year in the tropi- cal Indian Ocean. Differences in the amount of cross-equatorial heat transport and the estimated thermal eddy diffusivity, especially in the eastern Indian Ocean are noted. A heat budget analysis signifies the importance of the vertical diffusive heat flux and points to the role of positive shortwave flux bias in determining the warm SST bias. The MLD biases in the simulations are not due to possible wind stress forcing errors. In addition, the wind stress-MLD relationship is stronger for these schemes compared to the observations. The KPP simulated MLD is slightly sensitive to the critical bulk Richardson number and changing it from its default value of 0.25 to 0.15 can marginally improve MLD simulation in the Indian Ocean.

Keywords: Ocean Mixing,HYCOM,Indian Ocean,Interannual variability

Assessment of MOM6 simulated vertical profiles of temperature, salinity, density with respect to in situ observation over Northern Indian Ocean

[ABS-03-0235]

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Errors/biases in model simulated temperature, salinity and density can limit it's prediction/simulation skill. Physical processes for these errors/biases are important to know for a model prior to the operational services. Here, Modular Ocean Model version 6(MOM6) has been assessed with Argo/in-situ observation for the period 2004-2020. Argo temperature, salinity, density observations on 1°x1° horizontal resolution are used for the period 2004-2020. MOM6 developed by NOAA, GFDL has been used in this study with horizontal resolution .25° x .25° and with 75 vertical levels (hybrid depth isopycnal coordinate with order 2 m at the surface and nominally order 20 m at a depth of 200 m). The model equations are the layer-integrated vector-invariant form of the hydrostatic primitive equations (either Boussinesq or non-Boussinesq). Vertical structures of bias and errors for temperature, salinity, density and seasonal variability have been studied for upper 300m. The study region has been divided into four sub regions, Arabian Sea (40°E-85°E, 5°N-30°N), Bay of Bengal (80°E-100°E, 5°N-30°N), Equatorial Indian Ocean (40°E-110°E, 5°S-5°N), and Southern Indian Ocean (30°E-120°E, 0°S-30°S). Study period is divided in four seasons spring (March-April-May, summer (June-July-August-September), fall (October-November) and winter (December-January-February). 70 years spin up of MOM6 using Coordinated Ocean Ice Reference Experiment (CORE) climatological forcing has been done to get the dynamical stability. 50 years of interannual run from 1970-2020 with JRA55-do atmospheric forcing has been done. JRA55-do is the Japanese Reanalysis dataset for driving ocean models. It's horizontal resolution is .5° and temporal resolution is 3 hour. The maximum bias/error of temperature (~1/~1.5℃) observed at 100m depth in the AS. It is maximum in DJF season in AS. For salinity bias is increasing with depth and reaches maximum at ~100m. in all the season and all the regions considered. For

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RMSE, it has a decreasing trend with depth for salinity in all the regions and all the seasons. Density biases and error analysis are studied for above discussed seasons and regions. Study indicates that model overestimates mixing, leading to colder bias in the upper ocean and warmer bias in the subsurface, which might be minimized by revising diffusion coefficient profile.

Keywords: Ocean modelling, North Indian Ocean, temperature, salinity, error

Numerical modelling approach to assess the hydrodynamic conditions and phytoplankton community distributions due to seasonal changes at South Indian lagoon ecosystem

[ABS-03-0254]

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Pulicat lagoon located at east coast of South India exhibits high stress on the ecosystem habitat due to the natural and anthropogenic factors. This study focuses on the numerical model approach to assess the ecosystem for the seasons of 2018 to 2019 along with the field collected physical, chemical, biological and meteorological datasets. The integrated hydrodynamic and ecological model were used in this study to analyse the circulation features, biological and chemical interaction along with transformation processes. The study signifies that high abnormalities in the lagoon ecosystem is based on the less exchange of fresh/coastal water from river sources and sea mouth due to less rainfall during the study period. The model result shows the salinity variation between 15 PSU to 58 PSU in different seasons of 2018 & 2019. Moreover, high concentration of Chl-a ranges between 50 mg/m3 to 95 mg/m3 were observed during monsoon and post monsoon seasons, triggering the phytoplankton C (70 to 350 mg/m3) and zooplankton C (9 to 43 mg/m3) at the lagoon which leads to algal bloom. The biological field observation shows the monsoonal shift of Chlorophyte (9.52% to 9.68%), Cyanobacteria (13.22% to 14.95%), Diatoms (66.08% to 63.87%) and Dinoflagellates (11.18% to 11.51%) in which Diatom shows the higher abundance (~65%). Hence, in order to conserve and make the ecosystem to resilience during such extreme events, suitable scenario based model studies were performed by widening the lagoon inlet (~800m) with the depth of ~5 m (1.8km length) to increase the tidal exchange to the ecosystem. Model result shows the optimum exchange which normalize the salinity from 12 to 34 PSU from inner lagoon to the mouth region. This study will be helpful for the environmental authority to conserve the ecosystem with proper management adaptations.

Keywords: Hydrodynamics, ecological modelling, nutrients, lagoon ecosystem

Estimation of flood inundation and run-up along selected river banks of Kerala by numerical simulation studies

[ABS-03-0038]

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Abstract The state of Kerala located in the southern peninsula of India was in the shadow zone of several natural disasters. For the people of Kerala the term disaster was a matter of strange science fiction book and the things which were happening on the other side of the globe or planet. But the tsunami of 2004, Ockhi 0f 2017, Floods of 2018, replicated floods in 2019 , few landslides and landslips exposed our vulnerability. Immediately after each disaster the research and development associated with that also gained momentum. So post 2018, the state of Kerala is engrossed in establishing a flood warning system. The main component of a flood warning system is the prediction of flood inundation and run-up along the banks of rivers. The prediction of flood characteristics can only be done with the help of a numerical model. At this juncture this paper is an attempt to numerically model the flood inundation and run-up along three prominent river banks pertaining to South, North and Central Kerala. As real time data collection for initiating simulation studies are considered to be laborious, tedious and time consuming alternate sources of data such as the satellite data sets and an open source model was selected for this investigation. The model results predicted that Kerala is not at all vulnerable to floods for normal and moderate modes of rainfall. But significant inundation will arise for heavy rain fall and extreme rainfall events like the hypothetical mode of rainfall envisaged under this investigation. The simulation studies also showed that external discharges like dam discharge and tidal reflections can also lead to increased run-up and inundation levels. The investigation recommends computations emanating from fine resolution models and high resolution field verified data for successfully establishing an effective flood warning system.

Keywords: Inundation, run-up, Flood warning System, Simulation, Prediction

Thermal and non-thermal forcing attributed seasonal changes in surface pCO2 in the north Indian Ocean using a coupled model

[ABS-03-0492]

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In the last 250 years, human activities have led to an increase in atmospheric CO2, which is a known contributor to global warming and climate change. Atmospheric CO2 is rising at an alarming rate of 2.11 ppm year-1 globally and 2.13 ppm year-1 over the Arabian Sea. Increasing atmospheric CO2 has consequences for the marine ecosystem due to the hazard posed by ocean carbon uptake and the resulting ocean acidification. Here, we use a coupled atmospheric ocean biophysical model to analyze the thermal (sensitivity to temperature) and non-thermal (sensitivity to Dissolved Inorganic Carbon (DIC), Alkalinity (ALK) and Fresh Water) contributions to ocean surface pCO2 in the north Indian Ocean. The simulations are carried out from 2010 to 2020 at 25 km horizontal resolution. The atmospheric CO2 is incorporated into the model using combined satellite measurements so that the model can use spatially and temporally varying CO2 for the flux calculations. As the Arabian Sea (AS) and the Bay of Bengal (BoB) show large intra and inter-spatial variability of carbon dynamics, it is necessary to consider different regions to study separately. Henceforth, we select six boxes, three in each basin, at major upwelling, biophysically and dynamically active regions. The simulated carbon variables (ocean surface pCO2, DIC, and ALK) are validated with available datasets. In addition, the ocean surface pCO2 is compared with measurements from the BOBOA buoy. To assess the influence of thermal and non-thermal factors on ocean surface pCO2, we decomposed the ocean surface pCO2 into thermal and non-thermal components. We further analyze the influence of Mixed Layer Depth (MLD), Net Surface Heat Flux (SHFLUX) and Net Surface Salt Flux (SSFLUX) on the thermal and non-thermal components of ocean surface pCO2. We find that the non-thermal components show similar variability to MLD in most regions, with a large correlation (~0.8) in northern AS. The northern AS is characterized by

convection-induced vertical mixing during winter and a deep mixed layer. The DIC from the subsurface layer is uplifted to the surface, which results in high ocean surface pCO2. The thermal components are closely associated with SHFLUX in most regions. The upwelling regions such as Somali Coast and southeast AS exhibit positive correlations between non-thermal components and SHFLUX. Furthermore, we analyze the Revelle Factor (RF), which is an indication of the buffering capacity of the ocean to absorb CO2. High RF in the upwelling regions indicates the ocean?s low buffering capacity. We assess the pH of the north Indian Ocean to understand the current status of the ocean acidification in AS and BoB. The study gives insights into the carbon dynamics in the upwelling regions of the north Indian Ocean in the context of increasing atmospheric CO2. Major highlights of the study: ? An Ocean-Biophysical Atmosphere coupled model is configured to represent the carbon chemistry in the north Indian Ocean. ? Simulations were carried out from 2010 to 2020 with ¼° horizontal resolution. ? Atmospheric CO2 is incorporated into the model for the better representation of air-sea carbon flux. ? The model simulated ocean surface pCO2 is compared with available measurements and datasets. ? It is further decomposed into thermal and non-thermal components and their controlling factors are analysed. ? The high pCO2 northern AS is dominated by the non-thermal component and is controlled by the changes in MLD. ? The western coast of India and the southern BoB region is dominated by non-thermal components in both seasons (DJF and JJAS). ? Revelle factor indicates that the upwelling regions are more sensitive to DIC change than other regions. The study contributes to the sustainable goal of the UN Decade of Ocean Science, ?a predicted Ocean? by giving insights into the current status of carbon dynamics of the north Indian Ocean with a focus on upwelling and dynamically active regions.

Keywords: Coupled Model, Atmospheric CO2, ocean Surface pCO2, Ocean Acidification

Evaluation of model-simulated tropical cyclone's response on the biogeochemical parameter using profiling float observations in the Arabian Sea

[ABS-03-0489]

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The measurements from an BGC-Argo float were used to evaluate the impact of model resolution (~25 Km; ROMS-¼) to simulate physical and biogeochemical state during the Tropical Cyclone (TC) Ockhi in the north eastern Arabian Sea (16.36 °N and 69.66 °E). In response to TC Ockhi, the measurements from float showed a mixing of water column upto 95 m depth (mixing depth) through strong winds induced vertical mixing where mixed layer depth deepens only upto 49 m. This mixing impacts strongly on the biogeochemistry of the ocean by initially increasing chlorophyll by 0.3 mg m-3, and decreasing dissolved oxygen concentration to 173 μM at the near-surface. The chlorophyll concentration at near-surface further increased to 3.6 mg m-3 with increase in dissolved oxygen concentration to 209 μM which favoured phytoplankton growth that resulted in increase of estimated average primary productivity by 1 g C m-2 day-1 within 7-8 days after the passage of TC. Similar kinds of evolution were seen from the ROMS-¼ model but slight under estimation with observation in the chlorophyll concentration, primary productivity at the near surface in response to TC and took nearly 4 days to reach the maximum peak after the passage of TC. The analysis based on observation and model will be presented here.

Keywords: BGC-Argo float , chlorophyll, DO, ROMS, Tropical Cyclone (TC) Ockhi

A coupled ocean biophysical-atmosphere model for simulation of the biogeochemistry of the North Indian Ocean

[ABS-03-0392]

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The North Indian Ocean (NIO) consists of the Bay of Bengal and the Arabian Sea, which are different in physical and biological aspects. We customize a coupled ocean biophysical-atmosphere model to investigate the changes in the biogeochemistry of the NIO. Both atmospheric and ocean models are set to a horizontal resolution of 25 km. We validate the atmospheric fluxes such as 2m temperature, latent and sensible heat fluxes, and wind stress with reanalysis datasets and assimilated products to understand the model performance. The physical ocean parameters such as sea surface temperature (SST), sea surface salinity (SSS), and ocean currents are also investigated to evaluate the model performance. SST and SSS are well represented in coupled models in annual and seasonal scales. The biological parameters, Chlorophyll ¿ a (Chl¿a) and Nitrate (NO3) are also compared with the satellite and World Ocean Atlas Climatology in annual and seasonal timescales. The coupled model can reproduce the summer and winter blooms and associated physical mechanisms observed in the Arabian Sea. Besides this, the subsurface Chl¿a and nitrate are also analyzed using available bio-argo measurements and the coupled model simulates the subsurface Chl¿a and nitracline well. The depth of subsurface Chl¿a maximum is also well captured by the coupled model. The model performance is evaluated in different upwelling regions. More details about the model setup, model validation, and model analysis will be presented.

Keywords: Coupled model,Ocean biogeochemistry, Bloom,Nitrogen cycle

Forecasting of Sea Surface Temperature using machine learning and its applications

[ABS-03-0386]

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In ocean analysis, sea surface temperature (SST) is one of the most critical parameters. SST anomalies are crucial in identifying the coupled ocean and atmosphere phenomena like El Niño¿Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD). SST is one of the critical factors in the formation of Tropical cyclones (TC), and it varies significantly in the presence of TCs. Short and medium range SST forecasting is vital since it can aid in the detection of these extreme events. Usage of realistic forecasts of SST in high-resolution TC models will improve the estimation of its lifetime, intensity, and rainfall. Accuracy in SST forecasts has a tremendous economic and social impact. The forecasted SST can also help tackle the problem of gaps in satellite SST data. With the large-scale availability of high-resolution satellite data, data-driven techniques are gaining popularity and are being used for the short-range forecasting of SST. The current study presents a comparative analysis of popular data-driven SST forecast techniques regarding performance, features, and limitations. Support Vector Regression(SVR), Long-Short Term Memory(LSTM), Convolutional-LSTM, decision tree models that have demonstrated good performance in existing literature on SST have been considered. These models have been trained and tested on tropical cyclone basins and string upwelling regions in the northeastern Arabian Sea , northwestern Bay of Bengal and South Indian Ocean for a lead time of 1-7 days. The first-day prediction is close to the reference field with an average error between 0.19 °C and 0.2 °C for various methods used in the present study. This study concludes that LSTM, SVR and Convolutional-LSTM have yielded maximum accuracy. The average error of the three proposed methods for 7th-day prediction is about 0.24 °C. The proposed three methods can be more efficient in predicting SST by using the ensembling technique. The average prediction error of the weighted ensemble is about 0.2 °C which is superior to individual models.

Keywords: Sea Surface Temperature(SST), Machine Learning(ML), Prediction,Support Vector Regression(SVR), Long-Short Term Memory(LSTM), Convolutional-LSTM

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An Ensemble-based forecast sensitivity approach to estimate the impact of observations in atmospheric and ocean data assimilation System

[ABS-03-0347]

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Data impact studies have been conducted regularly to assess the value added by each observation type to the data assimilation (DA) systems in all the major operational weather forecast centers. Observing System Experiments (OSE) is the traditional method employed to estimate the impact of observations in a DA system, which involves removing a particular subset of observations from a DA system, and comparing the resultant forecast against the baseline run that assimilates the complete set of observations. In this study, we implement a novel ensemble-based forecast sensitivity to observation (EFSO) approach in a limited area model system to estimate the impact of satellite atmospheric motion vectors (AMV). The EFSO method utilizes the ensemble perturbations as a means to estimate the impact of observations in an Ensemble Kalman Filter DA system. The impact of AMV observation using the EFSO approach is performed during the intensification period of two tropical cyclones (TC) - Hudhud (2014) and Phailin (2013) formed over the Bay of Bengal. Results indicate that the AMV observations reduce the forecast error, in general. Further, it is found that the percentage of AMV observations with the positive impact for both the TCs is a little more than 50% that contributes to improving the forecasts while the rest of the observations degrades the forecasts. The experiments performed with the targeted domain indicate that observations over the upstream region show a larger positive impact when compared to that over the downstream region of the TC. The current approaches can be extended to Ocean Data Assimilation systems.

Keywords: Data Assimilation,Observation Impact,Tropical Cyclones

Synergistic approach of data-assimilation of satellite-based chlorophyll in coupled physical-biogeochemical numerical model: An application of OCM-3 data

[ABS-03-0273]

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A synergistic approach of combining observations of chlorophyll from satellite with simulations of chlorophyll from coupled physical ¿ biogeochemical model has been done to generate high resolution daily analysed fields of ocean surface chlorophyll. For the purpose, ensemble based particle filter technique is developed to assimilate satellite observations into coupled model. Unique feature of the technique is the use of boot strap technique with particle filter to generate particles to represent PDF of model chlorophyll. This approach has substantially reduced the computational time required for the generation of particles, which needs a distinct model run for each particle generation in the conventional particle filter technique. In this technique background fields of chlorophyll from coupled model is perturbed by the insertion of bias randomly to produce ensembles or particles. Higher weightage is assigned to the particles closer to observations and these strong particles are used to initialize the coupled model for the next time step, while the weaker particles get discarded. The analysed fields of chlorophyll are validated with available observations. Results show the efficacy of the technique to generate analysed chlorophyll fields of improved accuracy as compared to the simulated chlorophyll without satellite data assimilation

Keywords: OCM3, Analysed chlrophyll fields, particle filter,coupled physical-biogeochemical modelling

Illustrating model performance over time and space using single diagrams

[ABS-03-0215]

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Model states are often validated against observations to determine the correctness of the model. However, when comparing the state of a model to multiple spatially distributed in situ observations, there is no single diagram that can show the statistical measure of correlation, root mean square error, and standard deviations of the variable in question across all locations. We present a simple but efficient representation of the correlation, mean square error, and standard deviation of the model and observation at multiple in situ sites in a single diagram and call it a Performance in Space (PAS) diagram. We also present a diagram showing the comparison of model state and observation at a single site across multiple time windows in a single diagram and call it a Performance Over Time (PAT) diagram. We highlight the effectiveness of these diagrams with realistic ocean models and realistic in situ observations. Using a PAT plot, we show that the NEMO ocean model performs better in simulating ocean sea surface temperature during boreal winters compared to boreal summers. We also illustrate how PAS charts can be used to assess the effectiveness of data assimilation. Although the examples shown here are from the field of oceanography, the display mechanism can be extended to any field.

Keywords: Model validation,Root mean square error,Correlation,Standard deviation

Validation of NorESM experimental run output for sealevel in the North Indian Ocean

[ABS-03-0103]

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The model outputs of sea level variables are essential in assessing past climates, projecting long-term trends, and comprehending underlying processes. A fully validated model dataset with a long-term span that could resemble the actual sea level changes is extremely important. Because the North Indian Ocean's sea level is rising at a faster rate than other oceans, there is a necessity for validated model outputs. The novelty of this study is that the Norwegian Earth System Model's (NorESM) experimental run output of monthly sea surface height data of 0.50 x 0.50 resolution is validated for the first time over the NIO. Statistical metrics used for the proper validation of the model involve root-mean squared error (RMSE), spatial correlation, and linear regression analysis and made comparisons among the model data, tide gauge data along the coasts, and satellite altimetry. The spatial RMSE and correlation demonstrate the strong relationship between the model and observation datasets. The selected tide gauges on the west coast of India show a strong correlation with model data for sea level anomaly. The western boundaries of the Arabian Sea and the Bay of Bengal show the lowest correlation, particularly for the Chennai and Visakhapatnam coasts. Nevertheless, the sea level anomaly (SLA) of NorESM model data correlates well with the observations over the North Indian Ocean.

Keywords: NorESM, Model, validation, North Indian Ocean, SLA

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A high-resolution ecosystem model for the Kongsfjorden-Krossfjorden system: Implementation and evaluation

[ABS-03-0270]

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The Kongsfjorden and Krossfjorden fjords, located on the west coast of the Svalbard archipelago in the eastern Arctic Ocean are characterized by their dynamic nature and deep profiles influenced by various physical processes connected to the open ocean. The inflow of warm-saline Atlantic waters from the open ocean significantly impacts the physical and biogeochemical processes within these fjords. Additionally, the summer glacier discharge induces strong vertical density gradients, further influencing the seasonal variability of physical and biogeochemical processes within the fjords. Therefore ongoing changes in the Atlantic water flows and glacial melting in this part of the Arctic Ocean can have significant ecosystem implications in the region that needs detailed monitoring and understanding. Hence we set up a high-resolution regional model for the Kongsfjorden-Krossfjorden system integrating the ROMS 3.7 physical model and the NPZD ecosystem model, utilizing realistic forcings from 2013 to 2017. The model has a horizontal resolution of approximately 500m with 40 vertical levels. ECMWF-ERA5 data is employed to force the physical model, while HYCOM reanalysis data provides the initial and boundary conditions. The WOA climatology dataset is utilized for the ecosystem model's initial and boundary conditions. Our model aims to investigate the mechanisms behind the seasonal biogeochemical variability within the fjord system. The model simulations are compared with satellite and IndARC subsurface mooring data from Kongsfjorden for validation. The results demonstrate the model's ability to accurately reproduce realistic seasonal surface and subsurface features, as well as the variability of the physical and biogeochemical parameters in Kongsfjorden. Furthermore, the model will be utilized to explore seasonal and interannual variabilities and their controlling processes in these high-latitude fjord systems.

Keywords: Atlantic waters, Fjords,glacier discharge,ecosystem model, biogeochemical variability

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How large can the errors be in space-based sea surface salinity measurements for its effective applications: An Observing system simulation experiments (OSSE) study for the Bay of Bengal

[ABS-03-0383]

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Sea Surface salinity (SSS) is a critical parameter affecting various large and smaller scale oceanic processes. SSS measurements from space-borne sensors suffer from various errors, and therefore the sensor data is averaged at coarse spatial and temporal resolution. One of the major applications of space-based SSS is its utilization in constraining numerical ocean models to correct for salinity and associated processes. In this study, an effort has been made to quantify how much error can be tolerated in satellite SSS so that it can be assimilated effectively in numerical ocean models. To this end, a set of observing system simulation experiments (OSSE) is performed in which SSS data with different errors are assimilated in the ocean model, and its impact is seen on the simulated ocean state in the Bay of Bengal. SSS datasets are generated by incorporating errors ranging from 0.2 psu to 1 psu in Aquarius-derived SSS. In addition to a model run without assimilation, multiple assimilations experiments are conducted using Aquarius-derived SSS and SSS observations with added noise. The sensitivity of model simulations to the noise levels in the SSS observations is then analysed using Argo observations and inter-comparison among various model simulations. It was observed that the maximum effect of noise coincided with high salinity variability regions. The findings from the study enhance our comprehension of how changes in the ocean's state and processes are influenced by salinity and the associated noise in SSS observations. Furthermore, this research contributes to defining permissible noise levels in SSS observations for future salinity missions.

Keywords: Sea surface salinity ,bay of bengal

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A high-resolution numerical ocean model of the Arabian Sea: Evaluation using satellite and in-situ observations

[ABS-03-0451]

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In the present study, simulations from a high-resolution numerical ocean model configured for the Arabian Sea (AS) are evaluated against in situ and satellite observations. The model is based on the Massachusetts Institute of Technology general circulation model (MITgcm), which is configured at a 0.02o spatial resolution spanning the Arabian Sea from 35oE ¿ 78oE and 9oN ¿ 30oN. The model is initialised from January 2018 using initial conditions of temperature, salinity and velocities from a satellite data assimilative ocean model at 10km resolution. The lateral boundary at the southern part of the domain is updated every 6 hours using outputs of the satellite data assimilative ocean model. The model is integrated for the year 2018 with forcings from ERA-interim reanalysis. The simulations for the period February 2018 to December 2018 are compared with available satellite and insitu observations. It is observed that the model is able to simulate the observed variability of the region, and the fine-scale patterns in the sea surface temperature (SST) are qualitatively similar to what is seen in the high-resolution satellite-derived SST. Seasonal analysis reveals that the errors in SST are large (~0.8K) during the monsoon period, while they remain low (~0.3-0.4K) during other months. Regional and seasonal patterns of sea surface currents and sea level anomalies are also compared with altimeter observations. Model's capability to simulate very fine scale features is being assessed by making use of EOS-06 Ocean Color Monitor observations and also using Lagrangian-based techniques. Detailed results will be presented during the conference.

Keywords: High-resolution numerical ocean model, ERA-interim reanalysis, Satellite observations, SST, Sea Surface Currents, Sea Surface Salinity, Sea level anomalies

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Sub-Theme-04

Coastal and Open Ocean Processes

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ABS-02-0132	Long-term variability in temperature and dissolved oxygen at the Candolim time-series station	Damodar M. Shenoy
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Long-term variability in temperature and dissolved oxygen at the Candolim time-series station

[ABS-02-0132]

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The eastern Arabian Sea hosts the world's largest naturally occurring seasonal hypoxic zone. While the perennial oxygen minimum zone in the open Arabian Sea experiences denitrification, the coastal system is more intense and during some years the system turns anoxic, which has deleterious effects on the living resources. While previous studies suggested large inter-annual and decadal variations in the dissolved oxygen along the west coast of India (WCI), the controlling mechanisms remained elusive, mainly due to observational constraints. A recent modeling-based study suggested that the indigenous mode of the Indian Ocean natural climate variability, called the Indian Ocean Dipole (IOD), strongly controls the anoxic events along the WCI, with positive IOD phases preventing their occurrence. However, observational evidence for those remote influences of the natural climate modes of the Indian Ocean on the WCI oxygen variability is still lacking. Furthermore, under the climate change scenario, the oceans follow suit by absorbing a sizable portion of the heat generated as the atmosphere keeps warming up. One of the impacts of this heating is the loss of ocean's capacity to hold oxygen. This, combined with eutrophication and decreased ventilation, results in the oceans losing their net dissolved oxygen, a process known as deoxygenation. This loss of dissolved oxygen in the oceans impacts the biogeochemical cycling of essential elements and the flora and fauna. While major time-series sites worldwide have shown a decrease in oxygen concentrations, such information is missing from the Arabian Sea. Here, we present monthly observations between 1997 to 2021 from the Candolim Time Series (CaTS-G5) station off Goa, located on the WCI. This study shows the variation of surface as well as bottom temperature and dissolved oxygen at the CaTS-G5 station over a 24-year long period, thus providing a unique opportunity to address the above-unresolved issues

concerning the inter-annual and the recent decadal changes in the dissolved oxygen along this coast.

Keywords: Arabian Sea, Candolim time series, dissolved oxygen, long-term, anoxia

Inlet dynamics of Agniyar river flowing through the cauvery basin of Tamil Nadu

[ABS-04-0412]

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NIOT

Coastal inlets are characterized by seasonal variations due to the impacts of the monsoon wave regimes and rainy/dry seasons. Coastal Inlets along the East Coast of India remain closed for most of the year, resulting in negligible exchange with open coastal waters. Natural long sand spits often exist at the entrances of inlets, and the sand spit evolution is dependent on a combination of impacts from wave and tidal-induced currents, river flood discharge and littoral drift. It is important to keep inlets open for better water quality inside the inlets, floodwater discharge, navigation, and boosting tourism and fisheries potential. Agniyar River is a non-perennial river in the Indian state of Tamil Nadu that flows southeast into the Bay of Bengal. The river drains into the Bay of Bengal through two inlets, forming a delta. Agniyar River inlets used to remain open with a width of 250m throughout the year until the Gaja cyclone in 2018,after which an unusual formation of sand deposits was observed closing the Agniyar River inlets. Due to the closed river inlets, the fishermen who park their boats inside the inlets find it difficult to venture into the sea for their livelihood. Field investigations are carried out inside the inlet to understand the water level variations and flow dynamics. A numerical wave model was established to study the nearshore wave characteristics along the study area.This study uses satellite images to illustrate the morphological changes of the Agniyar inlet before and after the Gaja cyclone and the sand spit evolution. The paper also focuses on inlet dynamics by estimating seasonal variations in sediment transport patterns.

Keywords: Agniyar River, Coastal inlet, Sand spit, Inlet dynamics, Numerical model

Coastal upwelling along the East Coast of India and its impact on commercial fishing

[ABS-04-0493]

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Coastal Upwelling, the upward movement of waters rich in nutrients into the euphotic layer, is linked with phytoplankton blooms that form the foundation of the marine food web. The main coastal upwelling systems, which cover less than 1% of the ocean's surface, account for roughly 20% of all global fish production. Seasonally reversing monsoon winds are associated with the seasonal upwelling systems that are observed in the North Indian Ocean (NIO), like those along the coasts of Somalia, Oman, western and eastern India, Sri Lanka, and Southeast Asia. The western Bay of Bengal (BoB) coastal upwelling system along the east coast of India is characterised by the influence of multiple forcing mechanisms operating on distinct timescales. While, the intraseasonal and interannual drivers of coastal sea level variations are determined to be mesoscale eddies and equatorial waves, respectively, on a seasonal scale, however, coastal upwelling along the east coast of India is influenced by both the local alongshore windstress (AWS) and remote equatorial forcing. The role of coastally trapped Kelvin waves in modulating the seasonal variability of local AWS-driven coastal upwelling along the western BoB has been investigated here using a novel method of AWS estimation (Ray and Swain, 2023). The Sea surface temperature (SST) based upwelling index and AWS were found to be closely correlated along the southern section of India's east coast (between Kavali and Point Calimere), where the coastal upwelling was primarily driven by local AWS. Along the northern section of the coast (between Kashinagara and Kakinada), however, coastal upwelling was initiated by the first upwelling Kelvin wave, maintained by the weak regional AWS, and then terminated by the first downwelling Kelvin wave. Thus, our analysis (Ray et al., 2022) revealed that remote equatorial windstress controls the seasonal variability of coastal upwelling along the northern portion of the Indian east coast, whereas it was predominantly locally controlled along the southern portion of the coast. In addition to this analysis of its driving forces, we have also investigated the variability of thermal fronts associated with coastal upwelling. The upwelling of colder, deeper waters to

the surface results in SST cooling and thermal fronts are frequently generated as a consequence. Typically, these thermal fronts (which often occur in chlorophyll-rich regions of the ocean) are associated with significantly increased biological activity, including fish aggregation. Consequently, the detection of potential fishing zones (PFZs) entails the identification of such fronts from satellite or model SST and Chl-a data. Thus, the relationship between the formation of PFZs and coastal upwelling proxy variables was also investigated. As PFZ advisories play a crucial role in streamlining commercial fishing operations in India, this analysis enables us to investigate the implications of coastal upwelling for commercial fishing operations. During the seasonal coastal upwelling period, prominent PFZ generation was only observed along the southern portion of the east coast of India, the locally driven system. On seasonal timescales, a strong coherence was observed between the occurrence of AWS and PFZ. In addition, the temporal variation of these parameters revealed that the peak of PFZ activity coincided with the seasonal maxima of AWS. An improved understanding of the role of coastal upwelling in the generation of PFZs is potentially of great societal importance. It can enable the development of methods of detecting/forecasting the probability of formation of PFZs based on surface wind and SSHA observations which are not affected by the presence of monsoon clouds. Improved all-weather PFZ advisories can potentially contribute to the fulfillment of sustainable goal (c) of the UN Decade of Ocean Science as they help optimize fishing operations through reduction in man-hours and fuel consumptions. Further,

Keywords: Coastal Upwelling, Potential Fishing Zone, Remote forcing, upwelling, productivity

Time dependent Plume front fluctuation and Plume generated Internal wave propagation

[ABS-04-0007]

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Tide influenced plume front fluctuation and the coupled dynamics on the shelf off Kochi, southwest coast of India, were investigated using Finite Volume Community Ocean Model (FVCOM). The plume exhibited the features of both small and large-scale plumes and extended up to a distance of 5-15 km from the inlet with respect to tidal oscillations. The rivalry between river efflux and tidal phases modulates plume fronts on the shelf, where the density gradients are fortified or weakened by mixing dynamics. In low tides, the region near the inlets was almost homogenised (Richardson number<1). While in high tides, the region gets more stratified due to the transport of high saline ambient water towards the inlet and also by the decreasing kinetic energy (Richardson number>1). Strong stratified plume frontal regions with high Brunt Vaisala Frequency (N) could be active zones of internal wave generation when the flow decelerates from supercritical to subcritical. The release of accumulated potential energy during the transition phase of the tide from high tide to low tide generates the hydraulic jump. This disturbance in the N maximum zone, together with Froude number ≤1 condition (supercritical flow changed to subcritical flow), favours the generation and propagation of plume induced internal waves on the shelf. Satellite imageries corroborated the propagation of plume generated internal waves on the shelf off Kochi.

Keywords: Plume Front, Brunt Vaisala Frequency, Richardson Number, Froude Number, Internal waves, Southwest coast of India

Coastal morphology and Littoral process along Odisha Coast

[ABS-04-0026]

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Odisha coast extends from Lat. 17° 49' N - Long. 81° 24' E to Lat. 22° 34' N - Long. 87° 29' E. The 480 km long coastal stretch of Odisha is bordered by the states of West Bengal on the north and Andhra Pradesh on the south with the eastern and exposed coastal stretch facing the Bay of Bengal. With its general coastal orientation being SW-NE direction, the unique geological and depositional history has given rise to a variety of landforms, viz., i) high sand dunes of 10 m to 20 m Gopalpur, Chilika shore front, Konark, Puri, Paradip, ii) sand bars and formation of islands at river mouths, iii) barrier beach at Chilika lake shore front, iv) formation of longest barrier beach at north of Mahanadi mouth, v) formation of Hukitola bay and Gahirmatha coast and vi) long mud flats at Dhamra to Chandipur. The southern Odisha coastal region from Sonpur to Konark is mainly with open sea beaches and the largest brackish water laggon, i.e., Chilika Lake. Towards north, up to Dhamra, the region is influenced with presence of ports, Wheeler Island, Hukitola bay, Mahanadi River, Pentha sea beach and Bhitarkanika mangroves. North of Bhitarkanika Mangroves, there witnessed the only coast in India with open sea mangroves with shallow nearshore and vast intertidal area. The littoral drift values are higher all along the Odisha coast from Gopalpur to south of Dhamra reaching a gross transport of 1.39 x 106 m3/year. Similarly, the littoral drift values are comparatively lower along the coastal stretch from north Dhamra to Chandipur with a gross transport of 0.54 x 106 m3/year at Chandipur. The coastal stretch between Gopalpur and south Dhamra show accretion trend due to large sediment load brought by the rivers Rushikulya, Devi, Mahanadi and Dhamra. The annual net drift is almost negligible and called as nodal drift point along the stretch between north Dhamra and Chandipur. The reason for nodal drift is the bay formation, wide intertidal flats, presence of dense mangroves, silt & clay deposits at nearshore and low wave action.

Keywords: Littoral drift, nodal drift, nearshore, tide, wind, wave, current, Fair weather & monsoons.

Influence of changing wave dynamics due to grounding of the Bhagvati Prem vessel along Surathkal Coast, Karnataka, India

[ABS-04-0449]

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The incident involving the grounding of the Bhagvati Prem hopper dredging vessel near New Mangalore Port in September 2019 had several notable effects on the coastal area. The vessel, measuring approximately 114.6 meters in length and 21 meters in width, ended up grounded parallel to the beach, acting as a nearshore breakwater. This positioning caused a change in wave dynamics, leading to specific outcomes. One of the immediate effects of the vessel's grounding was that incoming waves started breaking along the seaward side of the vessel. This altered the energy level of the waves reaching the shore, leading to the formation of low-energy waves. The reduced wave energy had a significant impact on the coastal sediment transport, contributing to the accumulation of sediment on the beach. Prior to the grounding incident, a shoreline change assessment had been conducted in the 15.7 kilometer sediment cell. The study revealed that between 2016 and 2018, the coastline experienced erosion over a distance of 9.66 kilometers, while 4.5 kilometers showed accretion. However, after the grounding incident, from 2019 to 2023, there was a significant shift in the shoreline dynamics. The eroding coastline reduced to 5.08 kilometers, while the accreting coastline increased to 7.18 kilometers. Furthermore, the study provides information on the rate of shoreline change during the specified time periods. Between 2016 and 2018, the shoreline change rate ranged from -28.78 meters (erosion) to 7.02 meters (accretion). However, between 2019 and 2023, the rate ranged from -11.16 meters (erosion) to 14.53 meters (accretion). This suggests that the rate of erosion decreased, while the rate of accretion increased during the latter period. The results suggest a direct correlation between the grounding of the Bhagvati Prem vessel and the observed beach accretion. The vessel's presence acted as a barrier, altering the wave patterns and reducing wave energy, ultimately leading to sediment accumulation and shoreline progradation.

Keywords: wave dynamics, sediment transport,shoreline, beach erosion and accretion

Impact of ENSO and IOD on wave characteristics over the Bay of Bengal

[ABS-04-0407]

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Understanding the wave dynamics is vital for developing robust coastal resilience systems in the era of climate change uncertainty. Consequently, there is a need to investigate the influence of climatic modes on wave characteristics. This study examines the impact of two such modes, El Niño Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD), on wave characteristics in the Bay of Bengal (BoB) during September-October-November (SON). The wave parameters from ERA5 for 1980-2020 is used to make composties individually for El-Niño, La-Niña, positive IOD (pIOD), negative IOD (nIOD), and Normal Year (NY). The events are considered based on the Nino3.4 and Dipole Mode Index (source: OOPC-NOAA). The concurrence events of the ENSO and IOD are excluded. An event-wise anomaly of averaged wave characteristics w.r.t. NY are calculated. During NY, the mean values of wave parameters: significant wave height (Hs), maximum wave height (Hmax), mean wave period (Tmean), swell (Hsw), and seas height (Hss) across the BoB are found to be 1.42m, 2.71m, 8.40s, 1.30m, and 0.46m, respectively. El-Niño exhibited Hs anomalies of approximately zero near coastal rims of the BoB. In contrast, La-Niña showed higher positive anomaly near the northern- and eastern-BoB, indicating increased Hs activity compared to El-Niño. During pIOD, higher than normal wave activities were seen near the micro-tidal region of Tamil Nadu, while negative anomalies were observed over the rest of the BoB. On the contrary, the nIOD displayed the opposite behaviour. As Hsw contributes about 70% to the wave spectrum over the BoB, Hsw and Hmax exhibit similar patterns to Hs. However, signature of Hss are extended further into the open ocean. The mean wave period reveals an exactly opposite pattern of Hs during all events (except pIOD). This may be attributed to the fact that wind helps in generating more chaotic waves, which dissipate early and have reduced time periods. It was observed that the spatial distributions of the wave parameters corresponded to wind speed anomalies, indicating winds being the primary driver of wave activity over the BoB. Since, during post-monsoon, La-Niña and nIOD are associated with relatively stronger wind systems, they displayed higher wave activity.

Keywords: Wave, ENSO, IOD, Wind, Bay of Bengal

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Climatology of surface waves and its variability based on measured wave data near the Southwest coast of India
[ABS-04-0398]

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The significance of wave observations must be balanced, as they provide essential inputs for coastal planning, infrastructure design, and assessing the impact of climate change on coastal regions. Vizhinjam, situated on the southwest coast of India, is highly susceptible to wave-induced hazards due to its proximity to the Indian Ocean. Therefore, comprehending the wave characteristics in this area is crucial for effective coastal management and infrastructure development. This study utilized wave observations at a water depth of approximately 22 meters from 2015 to 2022. The analysis encompasses wave classification based on wave steepness, peak wave period, and interannual and climatology of different wave parameters. The findings reveal that young sea waves are the most prevalent wave type throughout the seasons, ranging from 66.12% during monsoon to 81.29% during fair weather. Sea waves contribute significantly across all seasons, ranging from 13.10% during the post-monsoon season to 33.88% during the monsoon season. Comparatively, matured swell waves have a lesser presence, ranging from 8.03% during the post-monsoon season to 13.59% during fair weather. No old swell waves, with wave steepness below 0.004, were observed. Regarding wave classification based on peak wave period, intermediate waves emerge as the most prevalent category across all seasons, surpassing short- and long-period waves. However, the distribution varies throughout the seasons. Intermediate waves dominate during fair weather (56.59%), while long-period waves prevail in the pre-monsoon season (54.40%). The monsoon season exhibits a significant presence of intermediate waves (63.01%). In contrast, the post-monsoon season experiences a more balanced distribution among the three classifications. The maximum significant wave heights (Hs) were recorded during two tropical cyclones in May (4.12m - Tauktae) and December (4.05m - Okhi), while the

minimum values ranged from 0.37m to 0.96m. The average peak wave period (Tp) remains relatively consistent, ranging from 11.55 seconds to 13.32 seconds. Similarly, the average zero-up-crossing wave period (Tz) ranges from 5.90 seconds to 7.12 seconds, with consistent maximum values of 20.00 seconds. The Tp and Tz values demonstrate consistency across seasons, indicating the presence of longer-period waves throughout the year.

Keywords: surface waves, climatology,Indian Ocean

Assessment of the interactions of Wind and Swell waves during the life cycle of Cyclonic Storms during pre & post monsoon seasons in the Bay of Bengal using in-situ and reanalysis data

[ABS-04-0179]

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This study examined the interactions of locally generated wind waves and remotely generated swell waves during the life cycle of Cyclonic Storms during pre & post monsoon seasons using the ERA5 wave parameters over the Bay of Bengal (BoB). As the existing observational data is not having the individual components of locally generated wind waves and remotely generated swell waves, the combined significant wave height (SWH) data is used for the analysis. Observational wave data from the coastal wave Rider Buoys (WRB) are used for analysis along the east coast of India during the life cycle of the cyclonic Storms that are formed in pre and post monsoon seasons of 2020 and 2021. From the analysis of ERA5 wave components it is observed that the interactions of wind waves and swell waves are not uniform in the four quadrants of the storm. The interactions are changing with the intensification of storm and also with the distance from the coast. And also it is observed that the interactions of these waves are changing from pre monsoon to post monsoon season associated with the change in the surface level wind speed and direction. The results revealed that during the analysis period, the ERA5 wave parameters overestimates/underestimates the significant wave height during pre-monsoon/post-monsoon seasons as compared to the WRB data. The detailed analysis of the relative contributions of wind and swell waves to the observed SWH during different cyclones in the BoB will be presented in this study. This study will help in understanding the variability of storm surges during its life cycle.

Keywords: Wave Rider Buoy, Significant Wave Height,ERA5,Wind waves,Swell waves

Wave climate variability along the selected erosional hotspots of Kerala

[ABS-04-0075]

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Coastal communities across the globe are at the greatest risk of climate change induced coastal erosion and inundation. Wave climate variability is one of the major causes of coastal erosion/inundation processes, together with anthropogenic activities. Knowledge and better understanding of the variability of waves is essential to carry out coastal protection works and for the prediction and warning of extreme events. Many studies have reported changes in the global and regional wave characteristics but the assessment and evaluation of wave climate and its variability particularly for erosional/inundation hotspots are limited. Present study uses well validated data simulated by the third generation wave model WAVEWATCH-III (WWIII) for a 15-year period from 2007¿2021. Kerala, one of the densely populated coastal state in the south west coast of India has been selected for the study. Kerala coast is exposed to high waves and has the second largest percentage of coastal erosion (65%) after West Bengal. Unlike earlier studies the present study aims to understand the inter annual, seasonal and monthly wave climate variability of total wind-generated waves, wind-seas, and swell waves along the selected hotspots of Kerala.

Keywords: Coastal erosion,Wavewatch-III,swell waves,wind seas

A Case study on the causative mechanism of Kallakkadal flash flooding event along the southwest coast of India.

[ABS-04-0065]

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High waves, without any sign in the local winds, sometimes cause severe flooding events along the southwest coast of India, locally known as the Kallakkadal events and cause major societal problems along the coasts. This study attempts to establish the link between high swell events in the North Indian Ocean (NIO) and meteorological conditions over the Southern Indian Ocean (SIO) and to find the mechanism by which swell waves create coastal flooding .The study uses a combination of in situ measurements and model simulations for 2018. This study shows that the Kallakkadal events are caused by swells propagating from the SIO. In this case, a severe low-pressure system named Cut-off-Low (COL) was observed over the SIO, which appeared to be quasi-stationary. Intensification of COL resulted in strong winds (25m/s) over a large fetch for three days which gave necessary conditions for the production of long-period swells. High waves generated in the fetch area propagate into NIO as swells with the aid of the strong equatorward wind. This study also identified the presence of infragravity waves (IGWs) in the coastal areas during flooding caused by these swell events showing that swell waves contribute a part of their energy in producing IGWs whose frequency is less than that of swell waves. The study hints that IGWs might influence coastal flooding during swell events.

Keywords: Kallakkadal,Cut off Low,Coastal flooding,Infragravity waves

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Mechanism of Coastal Upwelling along the Odisha Coast in presence of South-westerly Winds

[ABS-04-0481]

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Coastal Upwelling is an important oceanic process phenomenon in which cold nutrient-enriched water rises from the bottom layers of the ocean to the surface under favorable wind conditions, thereby increasing the biological productivity of the upwelling region. The Ekman transport showed the upwelling-favorable condition from April to August, but the SST and surface currents showed this from Mid-April to the first week of June. The downwelling Kelvin wave and low salinity-induced stratified ocean do not permit upwelling after June. The study also uses high-resolution Coastal Ocean dynamics applications radar (CODAR) derived surface current, Sea Surface Temperature (SST), and Altimetry tracks to study the tempo-spatial variability of the coastal upwelling during 2018. Three active and break phases of upwelling due to air-sea interactions are noticed from Mid-April to the first week of June 2018. The active phases lasted for about 15, 6, and 9 days. The wind intensity and direction change with time due to variability in the upwelling in this region. SST indicator showed an upwelling signature after 2¿4 days of favorable wind indicator. However, CODAR-derived surface currents showed different phases as the winds indicate. The horizontal extensions of the upwelled cold water vary from 75 km to 140 km in the active phases, and its horizontal extension is reduced to 45 km during the break phases. The temperature during upwelling drops up to −3.5℃. For the surface currents, the above ranges vary from 45 km to 135 km in active phases and are absent in break phases. This information can be beneficial in anticipating the movements of nutrients and fish. The study showed that wind-driven Ekman transport is not the indicator, but SST, surface current, and SLA are needed for monitoring the tempo-spatial variability of the coastal upwelling along the Odisha coast.

Keywords: Coastal upwelling, HF Radar, Scatterometer winds, Air-sea interaction, Upwelling index, Coastal trapped Kelvin Waves

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Role of local winds and remote forcing in coastal upwelling along the West Coast of India.

[ABS-04-0348]

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NIT ROURKELA

The upwelling phenomenon in the West coast of India(WCI) is significant due to it's environmental and economic impact on the Indian subcontinent. The study was done to understand the role of alongshore wind and remote forcing in upwelling along the WCI using decadal reanalysis data (2009-2018) of satellite derived parameter. The parameters such as wind, sea surface temperature (SST), sea surface height anomaly (SSHA), and chlorophyll-a concentration were chosen as the indicators of upwelling for understanding coastal upwelling features. Two upwelling indices, one based on wind (UIwind) and the other based on SST (UIsst) were used in the study. Spatiotemporal variability was observed in this study region, where the strongest upwelling intensity was observed in the South-west tip of India (8-9° latitude) indicated by coincident positive ET (Ekman Transport), strong negative UIsst (upwelling index sea surface temperature) and negative SSHA during July/August. Towards the North of 9° latitude the upwelling intensity decreases. The main driving force was the local wind, however, the speed of the wind in the WCI has been in decreasing trend since the last decade (Patel et. al., 2020). Additionally, the remote forcing i.e., coastal kelvin waves and Rossby waves plays a significant role in the upwelling system of the entire NIO.

Keywords: Coastal upwelling,Alongshore wind,Ekman Transport,Rossby wave,Kelvin wave

Numerical simulations of rip currents at RK Beach, Visakhapatnam using MIKE21 BW Model

[ABS-04-0262]

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Rip currents are strong, narrow, shore-normal and seaward flowing currents that originate within the surf zone as a result of the complex interaction between waves, currents, water levels, and the nearshore bathymetry. Rip currents pose a significant danger as they have the ability to forcefully pull surfers or nearby swimmers, regardless of their swimming proficiency, far away from the shoreline and accountable for many drownings around the world's beaches. Based on the data on drownings collected for the Visakhapatnam coast, it has been consistently observed that RK Beach, one of the renowned beaches in Visakhapatnam, has recorded the highest number of drowning fatalities. In this study, the Mike 21 BW (Boussinesq Waves), phase- averaged, and two-dimensional model was used to study the rip currents induced by rip channels. Nearshore surveyed bathymetry, wave information were the primary forcing for numerical model study. The numerical simulation depicted the rip current behavior with varying wave angles. The field surf zone drifter velocities, Rhodammine-B tracks, optical imagery and model studies are in synergy to understand the nature of rip currents and to study its characteristics. The velocities of rip currents were observed to be more intense in the rip neck region, gradually weakening as they entered the rip head region. The occurrence of rip currents varied based on the angle at which the waves approached the shore-normal and the height of the waves. The results showed that the MIKE 21 BW model has successfully to simulated the rip currents, especially channel induced rip currents and it was used to further study rip currents to investigate their characteristics under various wave climates.

Keywords: Rip channels, RK Beach, MIKE 21 BW, Rip currents, Visakhapatnam

Inversion layer variability and associated processes over the south-eastern Arabian Sea

[ABS-04-0144]

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Reversal of surface currents and associated changes in the transported tracers make the south-eastern Arabian Sea (SEAS) dynamically active during late April and early May when sea surface temperature (SST) exceeds 29.5°C. This high SST region is called the Arabian Sea Mini Warm Pool (ASMWP). It is speculated that the formation of a monsoon onset vortex, which influences the onset of the Indian summer monsoon, is associated with this warm temperature over the SEAS. Numerous studies have been conducted on the formation of ASMWP, but its formation mechanism is still not understood clearly. In November, the coastal Kelvin wave packets initiate the formation of an equatorward-flowing boundary current along the east coast of India, known as the East Indian Coastal Current (EICC). The EICC transports the low-saline Bay of Bengal water to the SEAS. When it reaches SEAS, the low saline and cold BoB water overlies above the warm and highly saline Arabian Sea water. This causes subsurface temperature maxima, also known as temperature inversion. This region is due for a long-term study of the subsurface properties associated with the inversion layer, which can provide additional insight into the formation process and its variability. Using long-term reanalysis data (1993-2019), a significant upward trend in the thickness of the inversion layer is observed over SEAS. Due to convective mixing, the mixed layer depth deepens, and the inversion layer is stretched, increasing the inversion layer thickness. The increase in the inversion layer thickness decreases its average heat content, suggesting a negative correlation between temperature inversion thickness and its strength. This is the first process of its kind described in our study. Following it, the SST variability in the ASMWP region is studied. Further, a coupled ocean-atmosphere model is configured over the SEAS to investigate the air-sea interaction over the ASMWP.

Keywords: Soth-eastern Arabian Sea,Inversion Layer Thickness,Vertical Stability,Convective Mixing

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Inference of tide induced current inside the Kandla Creek

[ABS-04-0035]

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One of the bursting activity areas for the Indian maritime sector is the Gulf of Kachchh (GoK), which is in the Gujarat state adjoining the north-western part of Arabian Sea. Petrochemical businesses and coastal shipping operations have dramatically surged along its coastline. The advancement in industrial activity has sparked concern about pollution, necessitating an assessment of the impacts on the ocean and the GoK. One of the two extremely active macro tidal systems in the north-western Arabian Sea is Gulf of Kachchh which is only next to Gulf of Khambhat. The flow field in the Gulf of Kachchh is well known to be mostly caused by tides, with the wind having minimal effect on currents. In case of any coastal developments, understanding the tide and flow characteristics of GoK under numerous tidal conditions covering a Spring-Neap tidal cycle is crucial to determine the hydrodynamic aspects of the coast. The author has attempted to infer the tide induced flow field in the GoK using the MIKE modelling suite Software. A flow modelling study has been attempted on how to interpret the tide induced currents at the mouth and upstream segment of Kandal Creek where it further bifurcates into Sara Creek and Phang Creek. With the average width of Kandla Creek from its mouth to upstream is about 750 m wide, the hydrodynamic behaviour doesn¿t change drastically in the Kandla Creek unlike other creeks with narrowing segment of upstream. The modelled flow field reveals that at the mouth of the Kandla Creek, the current velocity is approximately 2.75 m/s during spring tide and 2.25 m/s during neap tide. Based on the model studies, it is observed that intertidal region of Kandla Creek will get flooded during spring tide. It shows that the morphology of Kandla Creek is more dynamic and active with the influence of tides. However, present study reveals that the variation of current magnitude within the Kandla Creek is quite insignificant since the Kandla creek maintain an average creek width throughout.

Keywords: Tide, Wind, Current & MIKE suite software

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Analysis of sonic layer depth in the Bay of Bengal from Argo observations

[ABS-04-0480]

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The sonic layer depth (SLD) is an important parameter in the underwater acoustics, which plays a significant role in determining the refraction of sound rays in the upper ocean. The knowledge of SLD is essential in understanding and predicting the formation of surface sound duct (SSD) and shadow zone, which in turn is crucial for detecting underwater objects. The SLD is obtained from the vertical profile of sound speed that is affected by temperature and salinity. The thermohaline structure of the Bay of Bengal (BoB) exhibits a substantial spatiotemporal variability, which modulates the sound speed and eventually results in wide variability in SLD of this region. This study demonstrates the structure and spatiotemporal variability of SLD in the BoB region using the Argo observations during 2011 ¿ 2020. A total of 14246 quality-checked profiles are used in this analysis. The SLD is obtained from the sound speed profiles estimated from Argo temperature and salinity profiles using the UNESCO equation. The preliminary analysis shows that the SLD is minimum in Spring and gradually increases to the maximum in Winter. The sonic layer is mostly absent during the pre-monsoon period in the central BoB. The positive vertical gradient of sound speed above the SLD is largest in the northern BoB during the winter which is the combined effect of surface freshening and temperature inversion. The sound speed gradient above the SLD is mostly regulated by the vertical gradients of temperature and salinity rather than the hydrostatic pressure.

Keywords: Bay of Bengal, Sound speed, Sonic layer depth, Surface sound duct, Argo

Sar observation of internal waves over Bay of Bengal

[ABS-04-0291]

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Internal waves of distinct character from weak manifestation to strong signatures observed over Bay of Bengal using ALOS PALSAR L band SAR data. Bay of Bengal is one of the most complex and dynamic in nature. As it has a huge inflow of fresh water from various rivers and rivulets opening into the bay and due to the bay nature, an abrupt increase in depth favors the formation of internal wave activity upon tidal forcing. Internal wave activity is present all along the continental shelf edge of the Bay of Bengal and it is not confine to a particular region. Their wavelength, phase speed and amplitude may vary depending upon the oceanic environmental conditions as their appearance vary from weak solitons to strong wave groups/ packets. The wavelengths computed from the present study vary from 0.17 to 4.8 km. They generally propagate towards coast. Their phase speed ranges from 0.04 to 0.2 m/s. internal waves having different signatures (elevation and depression) observed and they exhibit complex nature like crossing each other, moving in different directions etc. Interestingly, they both co-existed simultaneously and crossing over each other in the Bay of Bengal. This may infer that either internal waves generated from the deep ocean propagating over shelf regions may gets reflected or river discharge may act as a force to disturb the stratified layers. The latter assumption needs further investigation. In the head bay of Bengal, A multiple internal wave groups observed to be moving in different directions. An attempt made to automated detection of internal wave features using SAR images. Roberts's edge detection technique used to detect and identify internal waves with significant features. As the internal waves propagates towards coastal regions, they tend to interact with the coastal phenomena and exhibit complex nature like refraction, dual polarity etc.

Keywords: Internal waves, wave length, Phase speed, polarity, river discharge, stratification

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Major physical drivers that sustain the column production in the Oceanic South Eastern Arabian Sea

[ABS-04-0232]

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The marine ecosystem of the South Eastern Arabian Sea (SEAS) can be categorized as shelf and oceanic regions. The shelf region is biologically productive during the season of summer (Jun-Sep) which is generated and sustained by the coastal upwelling induced by the Indian summer monsoon. The oceanic region (O-SEAS) is not well explored compared to the shelf region in terms of physical and biological aspects. Even though the oceanic region is termed oligotrophic in general, the presence of rich biological resources consisting of tuna, myctophids, squids, cuttlefish etc. is recorded in the region. The upper layer is oligotrophic, having surface Primary productivity values in the range (SM: 526.298 mgC/m2d, WM: 208.9957 mgC/m2d, SIM: 319 mgC/m2d, and FIM: 538.5469 mgC/m2d,) the only known primary level producers in the oceanic SEAS are the sub-surface chlorophyll maxima (SCM) which are significant during stratification. This study brings out the spatial and temporal variations of SCM in the O-SEAS and the physical factors that regulate the regional production potential. Data from FORV Sagar Sampada, collected during different cruises were utilized to understand the vertical distribution of chlorophyll and physical parameters. The SCM was found to be distributed throughout the O-SEAS including in the surrounding area of the Laccadive Islands, and shows a heterogeneous pattern in both space and time. The physical drivers regulating the SCM were addressed using satellite and model data sets from a spatial perspective. Apart from spring and winter, the presence of SCM was detected during summer too, but of weak intensity due to the wind activity and weak stratification. In addition to the basin-scale monsoon forcing, the mesoscale eddies (warm & cold core) dominate during spring and winter and also influence the SCM dynamics. Stratification is enhanced by the warm core eddies in the SEAS during spring leading to more abundance of phytoplankton in the subsurface.

Keywords: Subsurface chlorophyll maxima,Stratification,Mesoscale eddies,Oceanic-SEAS

Mesoscale eddy dynamics in the Eastern Arabian Sea

[ABS-04-0181]

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The present study aims to explore and quantify the characteristics and dynamics of mesoscale eddies in the eastern Arabian Sea (EAS), an area that has received less attention compared to the western Arabian Sea (WAS). We utilize 26 years of altimeter data and numerical simulations to achieve this. Our findings reveal that the continental slopes in the northern and southern parts of the EAS are critical regions for eddy generation. These eddies generally propagate westward at speeds ranging from 10 to 30 cm/s, with most of them dissipating before reaching the central Arabian Sea (AS). The seasonal distribution of eddies in the EAS region was also studied, and it was found that a higher number of eddies are formed in the EAS during winter (44.2%), followed by spring (40.9%), and summer (10.5%). In contrast, the WAS experiences a larger proportion of eddies during summer (36.4%), with winter (30%) and spring (24%) also contributing significantly. While the generation of eddies in the WAS is primarily influenced by the instability caused by strong monsoon winds, our analysis demonstrates that the winter season in the EAS is characterized by significant positive baroclinic instability. This instability is associated with the propagation of intraseasonal, coastally-trapped Kelvin Waves from the equatorial Indian Ocean to the Arabian Sea and subsequent Rossby wave radiation. Furthermore, our results highlight that remote forcing in the EAS has a more significant impact on setting up instabilities compared to local wind forcing. Estimations of eddy-induced transport indicate that mesoscale eddies contribute to approximately 22% and 8% of the westward transport of heat and salt, respectively, in the upper 100 m of the EAS. This effect is particularly prominent in the southern part, during winter, when low-saline water from the Bay of Bengal (BoB) intrudes into the AS.

Keywords: Meoscale eddies,Instability,Eastern Arabian Sea,Coastal Kelvin Waves

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Exploring the long-term shoreline morphology of Vizhinjam Coast using high-resolution satellite Images

[ABS-04-0377]

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The shoreline experiences significant changes due to human activities and natural processes, resulting in erosion and accretion. Studying the morphology of shorelines is a crucial tool for identifying the causes and impacts of coastal processes along the coast, which helps protect the ecosystem and facilitate future development. This study aims to examine the morphological changes from 2000 to 2022 along the Vizhinjam coast using a remote sensing and GIS approach. The research also presents a trend analysis of shoreline positions in critical locations. The accuracy of shoreline analysis from satellite data has been validated by comparing it with beach profile data and field-collected shoreline data. Additionally, satellite images of various resolutions have been compared to determine the difference. For a comparison between a 10m satellite image and a 1m satellite image, the average difference is 3.3m. Similarly, for a comparison between a 10m satellite image and a 5m satellite image, the average difference is 2.9m. In contrast, the average difference is 0.4m when comparing a 5m satellite image with a 1m satellite image and 0.3m for a comparison between a 2.5m satellite image and a 1m satellite image. The hotspots of erosion and accretion have been identified from the analysis. It can be noticed that Cyclone Ockhi had a significant impact on the shoreline on either side of the port, while the coast is recovering back to its previous form gradually. Recently, ten cyclones (Sagar, Mekuru, Luban, Vayu, Hikka, Kyarr, Maha, Pavan, Nisarga, Gati) formed in the Arabian Sea and hit the east coast of India in three years (2018-2020). Similarly, on the west coast of India, more cyclones and frequent depressions were also experienced since 2018 after cyclone Ockhi.

Keywords: Shoreline, high-resolution images,Cyclone

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A review and reassessment of sediment transport pattern along southwest coast of India

[ABS-04-0355]

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Sediment transport is a crucial oceanic process that plays a vital role in shaping coastal morphology and stability. The sediment transport patterns along the coast are site-specific and influenced by varying hydrodynamic conditions. The southwest coast of India, particularly Kerala, is a region with diverse coastal hydrodynamics and sediment transport patterns. Thus, understanding the sediment transport patterns in Kerala is of significant importance for coastal management and infrastructure development in the region. In this context, this paper reviews the major journal papers on sediment transport along the Kerala coast to gain a comprehensive understanding of the sediment transport pattern. The review considers fieldwork, remote sensing, and available literature as sources of information. The findings of the reassessment indicate that the southern Kerala coast exhibits northerly sediment transport, whereas the central Kerala coast exhibits southerly sediment transport. Furthermore, bidirectional sediment transport is also observed in some locations. The northern Kerala coast has a highly complex sediment transport pattern, with different locations exhibiting northerly-dominated, southerly-dominated, and bidirectional sediment transport patterns. This review and reassessment underscore the complex sediment transport pattern along the Kerala coast. It is crucial to undertake site-specific sediment transport estimation before implementing any structural interventions along the coast, as part of infrastructure development and coastal protective measures. The findings of this study are of international importance, as it highlights the need for a comprehensive understanding of sediment transport patterns to develop evidence-based coastal management policies and infrastructure development strategies.

Keywords: sediment transport, wave, harbour, breakwater, groin

Short-term shoreline change analysis after a coastal intervention of hybrid structure at Puducherry Coast

[ABS-04-0186]

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Understanding the dynamic changes of the coastline frequently is essential to inform and scientific management of the coast. Recently, Satellite image processing techniques play a vital role in providing shoreline change data due to the advancement of automated classification algorithms and the free availability of satellite images with various resolutions. This study investigates the shoreline dynamics over the past six years along the Puducherry coastal region, located on the southeast coast of India. Numerous studies published over the past decades have documented significant erosion on the northern side of the Port breakwater. In 2018, National Institute of Ocean Technology, Ministry of Earth Sciences, and India implemented an engineering intervention, a hybrid structure that has submerged reef and beach nourishment to restore the lost beach and protect the beach at Puducherry coast. The study duration is divided into two periods: 2016-2017 and 2018-2022, to focus on the period before and after the intervention. Sentinel-2 multi-temporal satellite images of 10 m resolution were used for the shoreline change analysis. A simplified semi-automated model was created using ArcGIS to extract the shoreline data. The high-water line (HWL) or wet/dry sediment line collected along the coast using RTK-GPS has been chosen as a shoreline indicator. The model's cross-validation with GPS-surveyed HWL and uncertainty errors yielded an RMSE of 2.43 m. The mean shoreline position was determined by calculating the mean of all available shoreline data within a month. The average shoreline position for each period of the study was then calculated by taking the average of the corresponding month's data. This data provides a representative estimate of where the shoreline is located on average during the study period. The rate of shoreline change for different periods has been determined using DSAS at every 20 m interval. The results indicated the formation of a new beach and its subsequent seasonal transformations. This study demonstrates that the use of satellite imagery with due consideration to the uncertainties could be one of the reliable methods for short-term shoreline change analysis.

Keywords: Shoreline change analysis, Satellite Images, DSAS, algorithms, Sentinel-2, Hybrid Structure, automated shoreline detection.

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Seasonal influences on sediment dynamics along tropical open coast beaches, Central West Coast of India

[ABS-04-0133]

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Understanding the Indian monsoon's distinctiveness through its impact on sediment dynamics along open coasts is an evolving phenomenon. The sediment dynamics plays very important role in understanding coastal morphodynamics. This study employs median grain size (D50) in establishing the potential links between sediment grain size variability and the broader oceanic physical processes. To that purpose, field studies on cross-shore sediment grain size distribution and wave attributes (significant wave height and wave period) were conducted for six tropical beaches along the Goa coast in the Central West coast of India (Baga, Candolim, Calangute, Utorda, Benaulim, and Cavelossim). The empirical description in the literature is compared to the measured profile data and mean grain size to investigate potential correlations. The comparison of sediment D50 value implies the prevalence of more strong energy processes during the monsoon period. This study also investigates the hydrodynamic scenario in the north and south region during pre and post monsoon.

Keywords: Sediment size, tropical coast, seasonal influence, beach profile, monsoon

Grain size variation - A complex interplay of coastal dynamics along Chandrabhaga Beach, East coast of Odisha, India

[ABS-04-0081]

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An extensive approach to grain size analysis of beach placer sands was carried out to decipher the paleo-depositional environment of Chandrabhaga beach. Grain size statistical parameters were used to infer depositional processes, sedimentation mechanism and the hydrodynamic energy conditions in addition to discriminate between numerous depositional environments. The grain size parameters show that the grains are fine to medium sand (2.33Φ to 1.36Φ), moderately well sorted (0.83Φ to0.60Φ), near symmetrical to very coarsely skewed (0.09 to -0.017), platy to leptokurtic (1.40 to 0.81) in nature. Abundance of medium to fine grain sands show the prevalence of comparatively moderate to low energy conditions in the beach. The fluctuating trend of sorting also corroborate the impact of river and monsoonal variation along the coast. The Linear discriminant function indicates a beach setting where aeolian (6.33%) process influence is minimal, a shallow marine deposition environment and 100% fluvial processes. The river Devi serves as the main drainage system in transporting the sediment flux. The current study highlights the interaction between sedimentary particles with coastal dynamic processes.

Keywords: Grain size analysis, hydrodynamic conditions, linear discriminant function, Chandrabhaga beach, Odisha

Assessment of sediment provenance and influence of paleoclimatic variability on the depositional environment at the Chilean continental margin in the last 400 Ka

[ABS-04-0076]

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The Antarctic Circumpolar Current (ACC) and the Cape Horn Current (CHC) are the two most prominent currents influencing the coastal Southeast Pacific depositional conditions along the Chilean margin. However, their role in controlling sediment depositional environment is least explored. Hence, this study aims to assess the sediment depositional environment near the Chilean coast during the late Pleistocene (400 to 15 ka). Clay minerals, major minerals, and grain size were examined in sediment core samples from the west of the Strait of Magellan (IODP Site U1542). The clay fraction consists of chlorite, illite, and smectite, which vary in response to major glacial-interglacial stages, suggesting a shift in the sedimentary provenances throughout the studied time. A higher abundance of chlorite during the glacial stages indicates that it might have come from a metamorphic source by the glacial system. Interglacial stages are marked by an abundance of illite, which indicates the chemical weathering of acidic rocks of the Andean batholith. The grain size data shows a higher abundance of fine silt deposition throughout the last 400 ka. The calculated statistical parameters show a fluctuation between terrigenous flux and marine deposition marked by poor to moderately sorted sediments. The poor sorting of the sediments suggests that the provenance of the deposits was close to the studied site. The bottom water current might also have impacted the interglacial deposition at this site, as suggested by the positive correlation between mean sortable silt size and sortable silt abundance (%). The semi-quantitative analysis of major minerals in sediment samples shows the abundance of bulk feldspar over quartz, suggesting that sediments are relatively immature and have come from nearby sources. The sources were the archipelagos along the Chilean margin, the Andean batholith, metamorphic

basement rocks of the Patagonia region, and aeolian dust. The continental fluvio-glacial system, the southern westerly wind, and the CHC influenced transportation and deposition.

Keywords: Cape Horn Current, Sediment provenance, Paleoceanography, Glacial-interglacial, Clay minerals

Assessing sedimentation pattern in the Mahanadi and Subarnarekha estuaries of the East Coast of India.

[ABS-04-0041]

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Estuaries are unique hydrological settings showing a transition from fresh riverine to saline ocean water. The sediment depositional environment in the estuaries is significantly influenced by the rate of influx of sediment and freshwater from the rivers as well as wave and tidal actions. Hence, the sediment core samples were collected from Mahanadi and Subarnarekha estuaries to access the characteristics of sediments and their variations over time. A multi-proxy approach is employed to assess the sedimentation pattern over the Mahanadi and Subarnarekha River estuaries. We took grain size distribution, major minerals, and clay minerals as the proxy to reconstruct the sedimentation pattern and influence of monsoonal precipitation on these estuaries. As the variation in the sediment discharge rate of the rain-fed Indian peninsular river is mainly influenced by the Indian summer monsoon (ISM), thus we can use different sediment data to interpret ISM precipitation variability. An increase in the grain size of sediments in the riverine end of the estuary infers an increase in the discharge rate of the river and the energy condition as a result of increased rainfall. However, the construction of dams and barrages significantly influenced the natural influx and sediment and freshwater into the estuaries. End member modelling analysis (EMMA) and Principal component analysis (PCA) have been carried out to correlate different sediment data to infer prevailing energy conditions. The major mineral analysis can infer the provenance of the sediment in the estuaries. The Mahanadi and Subarnarekha estuaries show a contrasting and complex sedimentation pattern, which may not only be linked with the ISM precipitation. Hence, this study suggests that the slopes of the basin, the varying geology in the catchment area, and the different rates of influx from tributaries, etc have influenced the sedimentation pattern in these estuaries.

Keywords: Estuary, Paleo-monsoon, EMMA, PCA, Grain size, Weathering, Provenance.

Applications of Kalman Filter technique in coastal Morphological Models

[ABS-04-0017]

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Continuous transport of sediments by winds, waves, currents, and tides are responsible for the nearshore coastal morphological changes. The hurdles in developing models to predict these morphological changes are challenging, because of the difficulties in representing the extremely complex flow field associated with the breaking waves which drive varied seabed sediments in the nearshore surf zone. In recent years, the need for predicting the morphological response in order to assess the vulnerability of coastal resources and to plan effective protective measures, has increased appreciably. Consequently, this had led to the development of several models for predicting the morphological changes in response to storm, seasonal, and longer-term environmental forcing of different spatial and temporal scales. The important among them being the Data-Driven Models. Data Driven Models are based on establishing a correlation between the environmental forcing and the shoreline response, which could be extended for predicting future events. Some of the accessible models for predicting morphology evolution are reviewed in the paper. The paper also discusses the recent developments in application of Kalman Filter technique to Coastal Morphological Models and presents the case study for Shoreline Observations of South Chennai Coast. In Kalman Filtering technique, given the initial state variables (or their guess values) of a dynamic system along with successive measurements on it, the corrected future system state is estimated assimilating the available measured data. The computational algorithm consists of two steps, the prediction or extrapolation and the updating or correction of the system state variables. The technique involved uses sparsely observed shoreline positions, relates them to wave forcing observable at close time intervals to generate updates of state variables. The data requirements of this model highlight the importance of maintaining long records of good quality observations and the need for continuing the data collection programs in the future. This method has the potential to incorporate

shore evolution processes of different space-time scales in the model, and hence would serve the needs of the coastal resource management agencies who currently emphasize on predictions of mesoscale morphological changes.

Keywords: Data Driven Model, Sediment Transport, Shoreline, Forecasting

Wave tranquility and prediction of shoreline evolution along a site on East coast of India

[ABS-04-0055]

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To ensure safe and smooth berthing operations of passengers and cargo inside a harbor, it is necessary to obtain desired wave tranquility. Also, it becomes necessary to predict the effect of proposed coastal structures on shoreline in order to save the coastal land under probable threat of erosion. In the present study, an attempt is made to check the effect of a proposed fishing harbor on the wave tranquility inside the harbor and on the shoreline in the near future. For this purpose, the site of Arjipalli in Odisha was selected. Mathematical model studies for wave tranquility, littoral drift distribution and shoreline evolution were carried out for the proposed layout. Based on the findings of the model studies several harbor layouts with different lengths, orientations and harbor entrance locations were studied. The wave tranquility studies were conducted in two stages; determination of near-shore wave climate from offshore climate using MIKE 21 SW model by wave transformation and assessment of wave tranquility in the proposed fishing harbour by MIKE 21 BW model. The model was simulated for predominant wave directions. Littoral drift model simulated the distribution of wave height and longshore current for a cross-shore coastal profile for the design period. Recommended layout having 1285m long south breakwater and 756m long north breakwater with 80m wide south-easterly opening as harbour entrance was found capable enough to satisfy the wave tranquillity criteria throughout the year inside the berthing region. Net sediment transport in a year is about 0.54 million cum and is towards north and the gross transport is of the order of 0.78 million cum. The maximum advancement of shoreline towards sea and the maximum advancement of shoreline towards land would be about 435 m in the up-drift direction and about 285 m in down-drift direction, respectively in 10 years.

Keywords: Wave transformation, Wave Tranquility, Coastal erosion, Littoral drift

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Evaluating the impact of opening of a coastal inlet on water quality using numerical modelling

[ABS-04-0319]

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The 30km coastal stretch of Tamil Nadu, India extending from Chennai Port to Katupalli Port has complex system of coastal structures and rivers. From South to North along the coast, breakwaters for Chennai Port, Chennai Fishery harbour, Ennore Port and Katupalli Port are present. The water from Kosasthalaiyar and Korattaliyar rivers, Amullavoyal and Buckingham canal meet the Bay of Bengal at Ennore creek. The creek remains closed for significant part of the year due to deposition of sediments, preventing the exchange of upstream river water in to the Bay of Bengal. The discharge of wastewater by various industries on the upstream ultimately leads to poor water quality conditions. The problem of poor water quality is exacerbated since there is no proper exchange of Kosasthalaiyar river water due to closure of the creek. National Institute of Ocean Technology was entrusted with the responsibility for identification of strategy for keeping Ennore creek open, which is complex due to the presence of various coastal structures. A scientific study involving comprehensive data collection followed by numerical modelling for morphological changes was carried out to identify suitable option for opening of the Ennore creek. Dredging of the creek from the mouth to upstream combined with construction of training walls was identified as the suitable option for opening of Ennore creek. The water quality in the region is poor and the opening of the creek shall result in improvement of water quality due to the tidal exchange. The changes in water quality have been predicted using numerical models. This paper focuses on the impact of opening Ennore creek on hydrodynamics and water quality.

Keywords: Ennore creek,water quality modelling ,inlet water quality

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Application of numerical modelling in river training structures for development of a fishery harbour

[ABS-04-0404]

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Design of a harbour layout is influenced by many factors like tides, waves, littoral drift and sedimentation in the region etc. At many places harbours have been developed in the vicinity of the River mouth. Careful planning is needed to develop harbour in such cases as the River flow regime may get adversely impacted due to development, resulting in increased sedimentation in the region and complete choking of the River. While mathematical modeling can provide an insight into prospective changes in flow condition, it may also be used to assess suitability of structures in preventing natural choking of mouth. A fishing harbour located at Maharashtra Coast in the mouth of a River was proposed to be expanded by construction of a Breakwater to prevent choking of Mouth. The response of the harbour with respect to variation in tidal heights, currents and wave actions has been studied to prevent choking of the river. In this paper, hydrodynamic conditions in the vicinity of the river mouth and in the harbour basin resulting due to the combined effect of tides and river flow has been studied using numerical modeling software Mike-21 to assess sedimentation in the region. The layout, which causes improved hydrodynamic condition in the vicinity of harbour area, is recommended as it will decrease sedimentation in the region. It was found that Breakwater of 730 m length up to -2 m contour and an approach channel with a base width of 80 m would be sufficient to reduce sedimentation at the mouth and prevent entry of littoral drift in the harbour area. However, based on operational requirement annual maintenance dredging estimated in the range of 15000 -20000 m3, should be carried out. There could be sedimentation on the lee side of reclamation and breakwater due to prevailing littoral drift but it will not modify the hydraulic conditions in the entrance channel and it will be safe for navigation.

Keywords: fishery harbour, hydrodynamics river training, Breakwater

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Seasonal variation and regulation of Chlorophyll-a in the Arabian Sea

[ABS-04-0409]

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The present study aims to understand the dynamics of Chlorophyll-a (Chl-a) variability in a comprehensive manner in seasonal timescales using both numerical simulation and observation datasets. The study provides many new contributions toward our understanding of the seasonal variability of Chl-a. The results have been shown from the climatological simulation with ROMS, the NPZD model. The Arabian Sea is the mini warm pool, which is a part of the Indian Ocean warm pool. The monsoonal reversal of winds and seasonal expansion of oceanic currents are responsible for pronounced biogeochemical variability over the basin. The summer and winter monsoonal winds are responsible for summer and winter blooms in the Arabian Sea. North-east and southwest monsoon seasons have a strong influence on the spatiotemporal variability of biogeochemical parameters in the Arabian Sea. In the central Arabian Sea, during the south-west monsoon, the high Chl-a, a bloom region, occurs due to strong cyclonic wind stress curl associated with Findlater Jet, which drives upward Ekman Pumping and upwelling, and surface chlorophyll maximum along 17˚N and 64˚E. During north-east monsoon, due to minimum temperature, maximum evaporation, negative heat flux, and evaporative heat loss drive convective mixing induced upwelling. The mixed layer is shallow during the southwest monsoon as compared to the northeast monsoon. In the western Arabian Sea during the southwest monsoon northward flowing Somali current, coastal upwelling, horizontal advection, Ekman pumping near the coast of Oman and Somalia, and Great Whirl induced very high Chl-a. During northeast monsoons, upwelling occurs due to convective mixing and weaker eddy activity. Despite maximum nitrate, phytoplankton concentration is less due to excessive grazing by zooplankton during the northeast monsoon. In the eastern Arabian Sea, during the south-west monsoon, elevated Chl-a along 12˚N to 15˚N and 17˚N to 19˚N in the Laccadive Sea due to propagation of Kelvin waves radiate as westward propagating Rossby waves into the Arabian Sea. The monsoonal variability of other biogeochemical parameters such as phytoplankton, zooplankton, nitrate, oxygen, and detritus has also been analyzed in the Arabian Sea.

Keywords: Chlorophyll-a, winter mon,summer monsoon,ROMS model

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Hydrodynamic modelling for highly anthropogenic coast of Puducherry

[ABS-09-0306]

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One dimensional hydrodynamic models are more suitable for open coast study but with highly developed and protected coasts it is unseemly. Process based models coupling multiple modules like hydrodynamics, spectral wave and sediment transport refines the understanding of coastal processes in an anthropogenic coast. The present study is conducted for Puducherry, in the South East coast of India having a combination of open coast and heavily built coastal structures like seawall, groins, offshore breakwater and harbour in a short spatial stretch. Two dimensional local scale model is setup using Mike 21 to study the response of coastal structure with respect to nearshore processes. The hydrodynamic forcings are taken from Global Tide Model and ERA5 reanalysis data for this study. The model is validated with measured tide, current velocity and wave direction data in the nearshore region of Puducherry coast at three locations. The seasonal sediment transport rates with respect to two dimensional model analysis are also presented.

Keywords: Numerical modelling, Hydrodynamics, Coastal structures, Anthropogenic, Puducherry

Influence of bottom and surface friction on the propagation of storm induced waters.

[ABS-04-0167]

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Storm surges frequently cause coastal flooding in India, having an extreme impact on human life, coastal infrastructure, and marine ecosystems. A key component of modeling for comprehending and reducing the effects of coastal storms is the accurate computation of storm tides and their accompanying landward intrusion. Observational analysis from ERA5 shows decrement of 30% - 50 % of wind intensity over the land compared to the adjacent ocean, particularly at landfall time for the cyclones: Bulbul (2019), Fani (2019), Titli (2018), and Thane (2011). Our modeling study comprises a fine-resolution mesh for the simulation of storm tides using ADCIRC (Advanced CIRCulation) model for India's east coast. The model uses land use/ land cover LULC - based roughness length and Manning's n coefficient for the calculation of surface and bottom stress, respectively. Experiments are conducted to quantify the effects of surface roughness and bottom friction on wind speed and the propagation of storm tides interior. Results from the first experiment show a significant decrease in wind speed of 15% -29% and an inundated area of 15% - 50% after including LULC in the model. In the second experiment, a hypothetical cyclone is used to conduct a sensitivity analysis to examine the effect of mangroves in the Krishna estuary after altering existing wetlands in the region. The experiment suggests that the presence of mangroves reduces the wind speed by 12.5% and the inundated area by 13.4%, respectively. When mangroves are considered in place of wetlands, bottom friction contributes 9.4%, whereas surface friction accounts for only 3%. This study suggests that further research and planning are necessary to guarantee the measures to restore coastal mangroves for efficient coastal management methods.

Keywords: Storm surges, Storm tides, LULC, Mangroves, Wetlands, Inundation

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Unravelling CDOM dynamics and source attribution in a Tropical Monsoon Lagoon: Implications for ecosystem functioning

[ABS-04-0049]

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Coloured dissolved organic matter (CDOM) is the optically measurable component of dissolved organic matter in water. These molecules are primarily leached from decaying detritus and organic matter. CDOM dynamics is expected to be highly variable due to the biogeochemical complexity of the study region and the season. CDOM are gaining greater attention for their photochemistry and photobiology activity in aquatic ecosystem by absorbing the ultraviolet (UV) and short-wavelength blue portions of the light. CDOM studies have mainly focused on coastal and offshore waters, whereas our understanding of their dynamics in tropical inland water bodies is relatively scarce. To bridge this knowledge gap, a monthly in situ investigation was carried out at 33 stations along a monsoon driven lagoon, Chilika, on the southeast coast of India for one year i.e., from July 2018 to June 2019. CDOM absorption at 440 nm [aCDOM (440)] data were analyzed as a proxy for CDOM concentration which varied between a range of 0.001 ¿ 65.14 m-1 with average values ranging between 1.70±2.67 m-1 and 3.76±5.55 m-1. A strong gradient in aCDOM(440) was observed from river discharge dominated shallower northern sector (4.9±8.33) to the more isolated and less fresh water influenced deeper southern sector (1.23±1.55). Spectral slope (S), spectral slope ratio (SR), and average molecular weight) (M), were computed to understand the possible source and fate of CDOM in the lagoon. The average spectral slope of S280–500 and S350–500 were found to vary between 0.002-0.096 nm−1and 0.001-0.095 nm−1, respectively. The (SR) and (M)-values were found to vary between a range of 0.01-7.81 and 0.31-52.28. It was observed that large-sized, high molecular weight CDOM from terrestrial origin was prevalent during monsoon with lower (S), (SR), and (M)-values. In contrast, lesser weight CDOM fractions were prevalent during pre- and post-monsoon, mainly of autochthonous origin with higher

(S), (SR), and (M)-values. Our results suggest the presence of a strong a spatio-temporal heterogeneity in the CDOM absorbance in Chilika that varies with monsoon driven freshwater input and interaction of fresh, brackish, and marine water continuum besides in situ modification of CDOM due to microbial degradation and precipitation.

Keywords: aCDOM(440) , Chilika Lagoon, Monsoon, M-value, Spectral Slope, Spatio-temporal

Unveiling upwelling dynamics and early onset of productivity along the West Coast of India: Insights from Long-term Observations

[ABS-04-0113]

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Upwelling, characterized by the movement of surface water away from the coast and the subsequent influx of cold, nutrient-rich subsurface waters, is critical in promoting enhanced productivity in coastal regions. This study investigates the upwelling dynamics along the west coast of India, focusing on its initiation, progression, and impact on coastal productivity. Our analysis of the upwelling time series reveals that the upwelling process along the west coast of India commences near 8°N during March and April. As the summer monsoon progresses in June and July, it gradually extends towards the northern region, reaching approximately 15°N. The mean vertical velocity relative to a depth of 100 meters is calculated to estimate the time required for coastal areas to attain enhanced productivity. Our findings suggest an average duration of approximately three months for this process. However, a notable observation of early temperature cooling challenges the previously mentioned estimation and indicates an earlier onset of productivity in the area. The Western Arabian Sea's advective nutrient flux is responsible for the early onset of productivity observed in this scenario. Additionally, variations in vertical velocity on a daily basis, followed by vertical mixing, are identified as additional factors that trigger this phenomenon. The insights gained from this study have significant implications for understanding and managing coastal ecosystems, fisheries, and marine resources. By shedding light on the complex dynamics of upwelling and its relationship with early-onset productivity, this research enhances our ability to predict and mitigate the impacts of environmental changes. The findings contribute to the broader knowledge of upwelling processes along the west coast of India and provide valuable insights for sustainable marine resource management.

Keywords: upwelling, west coast of India, ocean productivity

Dissolved and suspended nutrient complexity in a turbid creek-estuary confluence along the western India

[ABS-04-0040]

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The exchange between dissolved and particulate nutrients in ephemeral waters has significant potential for their enrichment and transport into the estuary and coastal waters along western India. The present study highlights such nutrient exchange at the conjunction of Thane Creek-Ulhas River, a sensitive urbanized creek-estuary ecosystem on west coast of India. The monthly monitored data potentially quantified the nutrient pools, mostly aligned with hydrography change and mixing. Except for salinity, seasonality was insignificant among hydrography properties such as temperature and pH ($p \geq 0.05$), owing to the hypo-synchronous flow and weak tidal conditions. The seasonal relationship between DO and COD in the Creek-estuary was related to the sporadic cyclonic rainfall events. The relative fraction of PO_4^{3-} and Org-P in total P were 49% and 42%, respectively, in Ulhas, whereas the PO_4^{3-} fractions in total P were higher than Org-P (43%) in Thane Creek. The positive relationship of LogKd of PO_4^{3-} and TP (R^2=0.66; $p \leq 0.05$) with lower SS (<25 mg/L) indicated stirring conditions for the nutrient exchange between dissolved and particulate phases in both the systems. The dominant nitrogen species, NO_3,$^-$ have contributed 60% and 56% to DIN in both systems. The temporal trends of NO_3^-/(NH_4^++DON+urea) indicated the dominance of regenerated nitrogen forms, except during June in Ulhas estuary and September in Thane Creek. The water quality and eutrophication (E) status assessed based on the physicochemical and nutrient parameters have indicated eutrophic condition (E>3) in ~30% of the data and hyper-eutrophic condition (E ≥6) in 10% of the data, mainly during pre-monsoon (March and May) in both the systems. The organic pollution index (A) primarily showed minimal contamination during SWM, and extreme rainfall, with occasional higher values in Thane highlighting the beginning of organic contamination. The waters at the confluence experienced noticeable temporal shifts

aligned with hydrographic change and exchange of nutrient forms, affected by the Ulhas River and point/non-point inland drainage networks discharge. The enrichment from the exchange of nutrients between dissolved and particulates has a further implication on the downstream estuarine and outflow creek waters, which pass through port-harbor networks and eco-sensitive zones (e.g., TCFS) before meeting the Arabian Sea.

Keywords: Thane creek; Ulhas estuary; nutrient exchange; eutrophication; organic pollution

Observation of wind speed dynamics in the northern Indian Ocean region and linkage to ocean productivity

[ABS-04-0335]

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Interaction between wind stress over the sea and geostrophic forces produces conditions in which water is pumped to the surface to supply the flow of diverging surface currents, with a scale of tens to hundreds of kilometers. Upwelling water is cooler and richer in nutrients than typical surface which leads to increased biological production. Wind exerts stress , results acceleration in wind direction, Coriolis force swings the current towards the right in the northern hemisphere (left in southern hemisphere). Within a few hours, it is moving at 90° to the wind and its velocity adjusts so that Coriolis force exactly balances wind stress, called Ekman transport. In coastal upwelling the wind blows parallel to the coast, or have a significant component parallel to the coast, to left of its direction in the northern hemisphere or to the right in the southern hemisphere. Wind speed is a useful parameter for the study of upwelling and has been considered in our study. Wind stress is calculated from wind speed which is directly proportional to Ekman mass transport. Upwelling intensity has been estimated from Ekman transport, which is perpendicular to the wind direction. Wind speed images is plotted for the year 2018 and averaged for every month in coastal and offshore Bay of Bengal and Arabian Sea using NCMRWF modelled wind data of 25x25 Kilometer resolution. The region between 0°N to 30°N latitude and 40°E to 100°E longitude is chosen for the study, which is part of the northern Indian Ocean. From the analysis of 2018 wind data, it is evident that the wind speed is maximum during the months of June, July and August, then onwards wind speed decreases during September and October and increases during November and December. During June-August, the southwest monsoon months and October-December, are the northeast monsoon months. Therefore, we observed wind speed is observed higher (10 to 15 m/sec) during monsoon months maximum during southwest monsoon period. There

has been enhancement in ocean chlorophyll concentration (>3.0 mg m-3) in upwelling dominated regions off coastal Kerala and in western Arabian Sea regions as observed using MODIS-Aqua satellite datasets.

Keywords: Ekman mass transport, Upwelling, Wind speed

Sub-Theme-05

Air-sea Interactions

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On the multi-scale resolution of near surface fluxes in the vicinity of 18N, 89E over the Bay of Bengal

[ABS-05-0417]

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Incois

Over the Bay of Bengal, the net heat flux variability is driven primarily by the shortwave and latent heat flux. The National Institute of Ocean Technology (NIOT) during the last two decades deployed moorings at strategic locations over the Bay of Bengal to monitor key climate variables. These buoys collect near surface and sub-surface data at hourly intervals. The focus of this article is multi -scale resolution of near surface fluxes in the vicinity of 18N, 89E using data from BD08 and BD09. Using a widely used bulk flux algorithm, the near surface fluxes of momentum, sensible and latent heat are computed for maximum available continuous data stretches. Multi scale resolution of the fluxes over the time-frequency space is carried out vis-a-vis their variability and regressed across winds, temperature and specific humidity. The scale dependent transfer coefficients C_d, C_h and C_e are further studied for their dependence on stability and near surface winds.

Keywords: Near surface fluxes,Wavelets ,Time-frequency ,Scale

Investigation on the climatological, ambient and remote forcing reasons and the prevalent ocean met roles for the intensification and genesis features of the ESCS Tauktae

[ABS-05-0455]

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According to a recent study, tropical cyclones are most likely to increase in the North Indian Ocean due to decreased wind shear and increased warming, especially in the Arabian Sea (increase in number), but a decrease in the BOB (Tiwari et al., 2022). In May 2021, Tauktae was an Extremely severe cyclonic storm (ESCS) occurred in the Arabian Sea (14 to 19 May 2021). The present study investigates the causative ocean-met factors in a climatological and current perspective and try to understand why it was getting intensified though it was traversed close (~ 140 km) to the coast. The datasets used for the study are from the observations (Moored buoys and RAMA), reanalysis (ERA5), and ocean model (ROMS). To understand the climatological conduciveness to intensification, the years (1981-2022) were classified into cyclone or non-cyclone years, and then the datasets were analysed. In general, the climatological Genesis Potential Index (GPI, which is a function of vorticity, relative humidity, wind shear and potential intensity) is higher off Indian west coast during the cyclone seasons in which low-level vorticity (LLV) and mid tropospheric relative humidity (MTRH) have major roles to play, and same is the case for May month. On top of that, just prior to the genesis of Tauktae, higher values of sea surface temperature (SST>29˚C), tropical cyclone heat potential (TCHP>100 kJ cm^{-2}), upper ocean heat content (UOHC), LLV and MTRH, and reduced vertical wind shear were observed, hence a higher value of GPI (>3) played a significant role in the intensification of Tauktae cyclone, which is apparent. Also, the translational speed of the cyclone was increased rapidly on 16 May, however, it was observed to be decreasing on 17 May during its rapid intensification (RI) stage, and which might have also added to the conduciveness to get the cyclone intensified. Moreover, ENSO (La-Nina) co-occurrence with a negative Indian Ocean dipole also seem to influence the intensification of Tauktae.

Keywords: Extremely severe cyclonic storm (ESCS) Tauktae, Genesis Potential Index (GPI), TCHP, Upper ocean heat content, translational speed, ENSO, IOD

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Impact of changes in atmospheric input on the oceanic primary productivity

[ABS-05-0329]

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Global oceanic regions are rapidly changing in terms of their temperature, oxygen, heat content, salinity and biogeochemistry. Since biogeochemistry of the oceans is important and key for global food production, and a major part of world population relies on marine resources for their daily life and livelihood, it is imperative to monitor and find the spatio-temporal changes in the primary productivity of oceans. Here, we estimate the changes in Chlorophyll-a (Chl-a) and Net Primary Productivity (NPP) in the north Indian Ocean (NIO) basins of Bay of Bengal and Arabian Sea for the period 1998¿2019. We find a substantial reduction in NPP in NIO since 1998 (-0.048 mg m-3 day-1 yr-1) and the increase in sea surface temperature (SST) (+0.02 °C yr-1) is the primary driver of this change. Furthermore, there is a substantial (10¿20%) change in air mass or dust transport from the previous decade (1998¿2008) to this decade (2009¿2019) to NIO. This change in air mass trajectories has also altered NPP in both basins through the nutrient input and associated biogeochemistry. Henceforth, this study cautions the changes in productivity of NIO, and suggests regular assessments and continuous monitoring of the physical and biological process in NIO in a perspective of food security and ecosystem dynamics.

Keywords: Climate Change, Air mass transport, Chlorophyll-a, Net Primary Productivity, AOD,Dust

Impact of extreme positive IOD on monthly summer monsoon rainfall over the Indian region in recent seasonal coupled global models

[ABS-05-0229]

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In this study, we assess the recently released twelve seasonal prediction models from the North American Multimodel Ensemble dataset (NMME) in simulating monthly mean state of sea surface temperature (SST) and monthly characteristics of extreme Indian Ocean dipole (IOD) positive phases against observations during 1990-2020. All models are initialized with May initial conditions. There is a significant warming trend in SST over the tropical Indian Ocean during the developing (June to August) and peak (September through November) phases of IOD seasons except for the western Arabian sea and southeastern Indian Ocean during the study period in both spatial and temporal aspects. Half of the models can simulate the SST warming trend over the Indian Ocean (IO). These trends mainly influence the Asian monsoon rainfall and associated circulation patterns. We have identified four extreme IOD (normalized values of IOD >2 in SON season) positive events based on interannual variability of SST anomalies during the study period. Based on the composite analysis, it is observed that the east-west SST anomaly gradient is higher during the SON than JJA season over the Indian Ocean. There is strong diversity in NMME models to represent monthly evaluation of SST anomalies over IO during the extreme positive IOD events when compared to observations. Similarly, to evaluate the composite of monthly accumulated rainfall over the Indian subcontinent, we built a 2x2 matrix contingency table and computed different skill scores during extreme positive IOD years. Results have shown that, from June to November, IC3-CanSIPS, GFDL_SPEAR, RSMAS_CCSM4, RSMAS_CCSM4, Gem_NEMO, and Gem_NEMO models have shown less RMSE, which is 70.68, 109.48, 94.6, 49.73, 26.65, and 18.55mm, respectively. The possible reasons could be the lack of incorporation of orographic features, misrepresentation of SSTA, and circulation patterns over IO during extreme positive

IOD events in the NMME models. This study provides insights into the merits and demerits of NMME models to simulate extreme positive IOD events associated with rainfall and circulation patterns over India and IO, which may be useful to improve seasonal prediction models for accurate prediction of extreme positive IOD.

Keywords: Indian Summer Monsoon, Indian Ocean Dipole, NMME models

Cluster analysis of tropical cyclogenesis locations in the Bay of Bengal

[ABS-05-0004]

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Tropical cyclones (TCs) are one of the most extreme weather events, harshly impacting every aspect of coastal civilization. Bay of Bengal (BoB) basin in the North Indian Ocean experiences multiple intense TCs every year. Although a decreasing trend of yearly TC frequency has been previously observed over the Bay, the intensification tendency has enhanced. However, the spatial changes in cyclogenesis locations in the BoB basin in recent times is not well studied. The current study looked into the spatio-temporal changes in cyclogenesis locations and the evolution of geophysical factors (sea surface temperature, relative vorticity, vertical wind shear, mid tropospheric relative humidity and convective available potential energy) over the basin during the 1991-2021 period. K-means clustering was carried out to assess the spatial evolution of cyclogenesis locations, whereas Empirical Orthogonal Function (EOF) analysis was employed to investigate the spatio-temporal variability of geophysical parameters. Cluster analysis identified three optimal clusters in the BoB region, with a shift of active cyclogenesis location from a cluster in southwest BoB to another cluster in northern BoB. The third cluster identified in southwest BoB was the least active in terms of cyclogenesis. The first EOF modes of met-ocean parameters showed a decrease in vertical wind shear and increase in the other four parameters, making most of the BoB basin highly favourable for cyclogenesis. However, the shift in cyclogenesis location towards higher latitude may be attributed to the observed increase in vertical wind shear in the low latitude region of BoB during recent times. The northward shift of active cyclogenesis region would mean more landfalls in the eastern coast of India, posing a serious threat to life and property in the region.

Keywords: K-means clustering,Tropical Cyclones,Bay of Bengal,Empirical Orthogonal Functions,Sea Surface Temperature

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Sub-seasonal air-sea interactions in the Bay of Bengal and a recipe for improving them in coupled ocean-atmosphere models

[ABS-05-0012]

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The impact of air-sea interactions in the Bay of Bengal (BoB) on the sub-seasonal modes of monsoon variability has been widely studied, especially that associated with active-break cycles of the monsoon. Due to the large amount of freshwater input from rivers and rainfall, BoB experiences high salinity stratification, which is known to affect the sea-surface temperature (SST) and convection on intra-seasonal timescales by influencing the ocean mixed layer and barrier layer. The connection between salinity stratification, sub-seasonal monsoon modes, and air-sea interactions is an area of ongoing research. This aspect is explored in a coupled climate model which includes an online river-routing module. This model indicates that thick barrier layers in the north-western Bay due to river freshwater limit the entrainment cooling of the mixed layer, leading to conducive oceanic conditions for the genesis of monsoon low-pressure systems (LPS) and affecting rainfall over India. Additionally, stronger northwest-oriented temperature gradients at synoptic timescales increase LPS lifetime and track density, resulting in more rainfall associated with LPS. Enhanced air-sea interactions restricted to the shallow mixed layer are linked to stronger vorticity, specific humidity, and low-level convergence to the north of the intra-seasonal convection band, which causes stronger and faster northward propagation of intra-seasonal convection band, aiding LPS activity. It is evident that improved simulation of air-sea interactions in coupled climate models can improve the representation of sub-seasonal monsoon variability, which can enhance the model's skill at simulating the seasonal mean monsoon. These findings have significant implications for operational forecasting

Keywords: Air-sea interactions,Bay of Bengal,rivers,monsoon low-pressure systems,monsoon intra-seasonal oscillations

Mixed layer-barrier layer interactions during tropical cyclones in the Bay of Bengal: A case study.

[ABS-05-0032]

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Tropical cyclones-induced mixed-layer (ML) cooling is a significant factor in controlling the intensity of cyclones. The presence of a barrier layer (BL) in the regions where cyclones are passing through can influence this ML cooling and, thereby, the cyclone intensity. This study analyzes the ML-BL interactions during cyclones, taking four tropical cyclones that originated and developed in the Bay of Bengal for a case study. A tropical ocean dynamic-thermodynamic model is employed to simulate the ML-BL responses in the Bay of Bengal during the above four tropical cyclones. The model was forced with hourly surface fluxes and meteorological parameters and ran for 2-3 months, covering the cyclone's duration. The mixed layer heat budget for each cyclone is also calculated to determine the relative contributions of various mixed layer physical processes, such as net heat flux, entrainment, horizontal advection, and vertical mixing, to the cooling of ML during the cyclone. Our analyses conclude that vertical mixing is the primary contributor to cyclone-induced mixed layer cooling in the Bay of Bengal. However, an absolute balance between the sum of all mixed layer physical processes and the ML temperature tendency is not achieved, indicative of the presence of BL and isothermal layer (IL), which needs to be accounted for in the mixed layer heat budget. A co-evolution of ML and BL in the BoB during the passage of the tropical cyclones is noted in the model simulations. It has also been concluded that the sudden response of ML and BL to cyclones may be of more dynamic reasons than the mixing mechanism itself.

Keywords: Tropical Cyclones,Mixed layer,Barrier layer,Ocean Dynamic Thermodynamic Model

Role of BSISO on the occurrences of Marine Heatwave events over the North Bay of Bengal

[ABS-05-0047]

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The present study investigates the properties of Marine Heatwave (MHW) events over the Bay of Bengal (BoB) during the boreal summer monsoon season. In recent decades (2001-2021), an increase in the frequency and duration of MHW events has been depicted. The rapid ocean warming primarily drives this accelerated trend in MHW events duration and is a significant concern for the scientific and fisheries communities. Tropical intraseasonal oscillations are one of the dominant modes that control the oceanic and atmospheric processes. Here, we have investigated the role of northward propagating monsoon intraseasonal oscillations (MISO) on MHW events over the north BoB during the boreal summer (monsoon season). It is found that during the break phases of MISO, enhanced shortwave radiation due to clear sky conditions triggers the MHW events. In addition, shallow mixed layer depth (MLD) also mostly favours MHW events over the north BoB during the break phases of MISO. However, during the active phases of MISO, negative SST anomalies and fewer MHW events are depicted over the north BoB. This strong relationship between shallow MLD and the occurrences of MHW events primarily indicates the connection of regional air-sea heat flux in driving the MHW events over the north BoB. The consequences of MHW events on socioeconomic status are also projected to be extensive, severe, and persistent throughout the 21st century.

Keywords: Marine heat waves; Boreal summer monsoon; Mixed Layer Depth

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Analysis of meridional heat transport over Indian Ocean in 1982-2017 period

[ABS-05-0058]

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The Indian Ocean Dipole(IOD) has strong influence on the Meridional Heat Transport(MHT) during late summer and fall, which is consistent with the seasonal phase-locking characteristics of IOD itself and the MHT anomaly caused by anomalous meridional velocity, which is induced by wind, is the major contributor of the total MHT anomalies and that there is anomalous heat transport from the equatorial region to higher latitudes in both hemispheres during IOD events, and the anomalous poleward MHT occurs mainly in the western Indian Ocean (Shuangwen Sun et al., 2014). The composite of MHT anomalies is positive in NIO and negative in SIO, indicating that there is anomalous heat transport from the equatorial region to higher latitudes in both hemispheres and It also shows that major MHT anomalies occur within 10°S and 10°N, and decay as latitude increases. The magnitudes of the poleward MHT anomalies more in the NIO and less in SIO. During JJAS season high poleward MHT observed than annual mean among the 1982-2017. An area of 5°S to 15°S (5°N to 20°N) playing a major role in transporting heat southward (northward) during JJAS in some years during annual and JJAS season also. But these southward heat transport was not that much strong during annual mean period. The surface winds over the tropical Indian Ocean experiences large changes, especially in its zonal wind component over the Equator (Saji and Vinayachandran 1999). During Elnino years easterly (southward and southeast ward) wind stress occurred at equatorial(southern hemisphere) region it take way to transport heat westward(southward), while in Lanina years high magnitude wind stress 2.80 N/m2 observed at from equator to 10°S and northerly wind stress occurred in Bay of Bengal and Arabian sea region. During PIOD years southerly winds observed over southern Indian ocean while in NIOD years easterly windstress 1.0 N/m2 occurred in southern equatorial region and it converted to south-east ward with 2.80 N/m2 magnitude. Among the entire Indian ocean the western Indian Ocean is most active transporting heat from equatrial region to higher latitudes than central and eastern Indian Ocean in both hemispheres.

Keywords: Meridional Heat Transport, PIOD, NIOD, Wind Stress, El Nino years

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Exploring air-sea CO2 flux parameterizations in Bay of Bengal: A tropical cyclone perspective

[ABS-05-0193]

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The transfer of CO2 gas between ocean and atmosphere plays a significant role in regulating the Earth's climate. In this context, extreme transient events like tropical cyclones (TCs) which can effectuate enhanced effluxes of CO2 from the ocean to the atmosphere play an important role in controlling global carbon cycles. In this study, the turbulent transfers of momentum and the resultant fluxes of CO2 across air-sea interface are estimated using different types of parameterizations available in the literature for eight TCs in the Bay of Bengal. The comparison of estimated CO2 transfer velocity and the results of wind-wave tank experiments reveal that among wind parameterizations the hybrid parameterization proposed by Nightingale et al. (2000) comes out to be closest (magnitude) in the high wind speed regime while all other linear and quadratic parameterizations used in this study underestimate the transfer velocities at high winds. Both the wave dependent parameterizations of CO2 transfer velocity considered in this study perform better than all wind-only parameterizations when compared with available experimental measurements. The resultant fluxes of CO2 from the choice of parameterization vary considerably among the various wind parameterizations and the difference between the wind and wave dependent parameterized fluxes are significant. In the present conditions of global climate variability, the segregation of estimation techniques of fluxes and carbon budgets under extreme conditions is paramount in helping the convergence of the community efforts of model-data inter-comparisons.

Keywords: Air-sea CO2 flux, Flux parameterization, Bay of Bengal, Tropical Cyclones

Local ocean-atmosphere interaction in Indian summer monsoon multi-decadal variability

[ABS-05-0067]

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The significant multi-decadal mode (MDM) of the Indian summer monsoon rainfall (ISMR) during the past two millennia provides a basis for decadal predictability of the ISMR and has a strong association with the North-Atlantic (NA) variability with the Atlantic Multi-decadal Oscillation (AMO) as a potential external driver. It is also known that the annual cycles and interannual variability of ISMR and sea surface temperatures (SST) over the tropical Indian Ocean (IO) are strongly coupled. However, the role of local air¿sea interactions in maintaining or modifying the ISMR MDM remains unknown. A related puzzle we identify is that the IO SST has an increasing trend during two opposite phases of the ISMR MDM, namely during an increasing phase of ISMR (1901¿1957) as well as a decreasing phase of ISMR (1958¿2007). Here, using a twentieth-century reanalysis (20CR), we examine the role of air-sea interactions in maintaining two opposite phases of the ISMR MDM and unravel that the Bjerknes feedback is at the heart of maintaining the ISMR MDM but cannot explain the increasing trend of SST in the tropical IO during the opposite phases. Large-scale low-level vorticity influence on SST and net heat flux changes through circulation and cloudiness changes associated with the two phases of the ISMR MDM together contribute to the SST trends. The decreasing trend of low-level wind convergence during the period between 1958 and 2007 is a determining factor for the decreasing trend of ISMR in the backdrop of an increasing trend of atmospheric moisture content. Consistent with the lead of the AMO with respect to ISMR by about a decade, the AMO drives the transition from one phase of ISMR MDM to another by changing its phase first and setting up low-level equatorial zonal winds conducive for the transition.

Keywords: Multi-decadal mode,Tropical Indian ocean,Bjerknes feedback,Large-scale vorticity feedback,Net heat flux

Dimethyl Sulfide (DMS) Emissions: Sea water concentration and Sea-Air Fluxes

[ABS-05-0085]

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Dimethyl sulfide (DMS) is a naturally occurring trace gas which affects the Earth's radiation budget by changing radiative forcing through the formation of sulfate aerosols. Considering the spatial and temporal variability of seawater DMS, various climatologies have estimated the global distribution of DMS. In this study, the differences between estimations of seawater DMS, based on latest observation-based interpolation (Hulswar et al., 2022)(H22)) and proxy-based parameterization methods ((Galí et al., 2018)(G18) and (Wang et al., 2020)(W20)) are analyzed. Compared to the parameterization-based methods, interpolation-based methods show higher DMS concentrations. The parameterization-based methods also suggest positive significant long-term trends in seawater DMS (6.95 ±1.41% decade-1 for G18 and 3.53 ±0.53% decade-1 for W20). However large differences, often more than 100%, are observed between the different estimations suggesting that sea-air fluxes and hence the impact of DMS on the radiative budget will be sensitive to the estimation used. Further the total flux to the atmosphere in models is calculated using a seawater DMS concentration climatology and a sea-air flux parameterization. To calculate DMS flux eight flux parameterization methods ((Liss and Merlivat, 1986; Wanninkhof, 1992; Erickson, 1993; Nightingale et al., 2000; Ho et al., 2006; Goddijn-Murphy et al., 2012; Wanninkhof, 2014)(LM86,W92,E93,N00a,N00b,Ho06,GM12,W14)) are used. After taking seasonal mean of calculated fluxes, the most used flux parameterization (N00a) is compared with other parametrizations to identify differences in absolute values and spatial distribution. In-situ flux observations are used to validate calculated fluxes of all parameterization. From regression analysis, we find that all methods fail to reproduce fluxes above 10 μmol m-2 d-1 and overestimate DMS flux in lower range (<10 μmol m-2 d-1) and underestimate in higher range (>20 μmol m-2 d-1). We observed that there are regions where uncertainty in DMS flux is driven by uncertainty

in seawater DMS concentration but in other regions, the choice of the flux parameterization will drive absolute flux values.

Keywords: Dimethyl Sulfide, Sulfate aerosols,flux parameterization ,interpolation, trends ,radiative budget ,climatology

A new method for the advance forecast of cyclogenesis index over North Indian Ocean

[ABS-05-0171]

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Forecasting of Tropical cyclones (TC) is highly impossible for meteorologists, as many parameters affect the genesis and intensification of tropical cyclones. Particularly atmospheric and oceanic parameters both play a crucial role in the genesis and intensification of cyclones. Based on previous studies, better results were obtained with oceanic parameters when compared to atmospheric parameters. In a previous study, a new GPI to forecast the genesis of tropical cyclones by using atmospheric and oceanic parameters was found. The present study is a continuation of our earlier study. A case study on the tropical cyclone over the Bay of Bengal from the genesis date to the one week preceding the genesis was recognized as cyclone spin-up time. Based on the results, it was observed that some of the oceanic and atmospheric parameters have a good indication for the forecast of the genesis and intensification of Tropical cyclones few days in advance. Our new GPI, by using oceanic parameters like UOHC (Upper Ocean Heat Content) and SSHA (Sea Surface Height Anomaly) has an excellent indication to forecast the cyclogenesis a few days in advance compared to the existing GPI mainly based on the atmospheric parameters (low level vorticity, mid troposphere humidity, thermal instability and wind shear between 200hPa and 850hPa) which are presently used by the India Meteorological Department (IMD). It is found that the area of cyclogenesis was observed well in advance compared with that the GPI using atmospheric parameters.

Keywords: Genesis Potential Index; Bay of Bengal; Tropical Cyclone; Forecast; Upper Ocean Heat Content; Sea Surface Height Anomaly

Northeastward movement of tropical cyclone mocha and influence of western disturbances

[ABS-05-0188]

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A well-marked low-pressure system (1006 hPa) formed over low latitude in the Bay of Bengal (BoB) during 00 UTC on May 9, 2023, and developed into an extremely severe cyclonic storm (ESCS) named "Mocha" on May 12, 2023. The Mocha cyclone moved in a north-northwestward direction and passed through Bangladesh and the north Myanmar coasts, affecting the cities, Cox's Bazar (Bangladesh) and Kyaukpyu (Myanmar), on May 14, 2023, at 06 UTC. The eyewall structure of Mocha entered these coastal areas and caused heavy rainfall along with gusty winds over Bangladesh, Myanmar, and adjoining regions. The major environmental factors for the genesis of tropical cyclone (TC) Mocha, such as wind at 850 and 200 hPa, relative vorticity, vertical wind shear, mid-tropospheric relative humidity, sea surface temperature (SST), and rainfall, are analysed from the NCMRWF global and regional models and compared with ERA5, and IMD satellite observations. The results show that the western disturbance (WD) plays a very crucial role in allowing the Mocha cyclone to move in northeast directions and it has been well captured by the models. In addition, the observations such as SSMI and NOAA SST are analysed to understand the marine heat wave (MHW), which characterised the warming conditions over the BoB and perhaps created a favourable environment for the rapid intensification and moisture supply from the boundary layer to the upper tropospheric region.

Keywords: Tropical Cyclone; Western Disturbance; Marine Heat Waves

Analysis of a high concentration CO2 pool over the Indo-Pacific warm pool using satellite measurements

[ABS-05-0393]

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Atmospheric CO2 levels have increased due to excessive emissions since the beginning of the industrial revolution. It is then passed to the biosphere and oceans, shifting the equilibrium of the natural carbon cycle and contributing to increased global temperatures by absorbing outgoing longwave radiation and re-emitting it. Here, we analyze the characteristics and variability of this region of high CO2 concentration (CO2 pool) in the middle troposphere above the Indo-Pacific Warm Pool (IPWP), where the CO2 concentration is higher than in the 20° N¿20° S latitude band. The ascending branch of the Walker circulations transports the CO_2 emissions from the surface to the middle and upper troposphere. The annual average trend for the CO2 pool is 2.17 ppm/year. With a mean percentage of 74.87, the western Pacific Ocean retains most of the CO2 pool, whereas the eastern Indian Ocean retains 25.13 percent. El Niño suppresses the CO_2 pool whereas, La Niña enhances it. The increased CO_2 venting during La Niña events and together with other emissions from land regions, the outgassed CO_2 is transported to higher altitudes by vertical winds. The immediate responses of the climate modes are captured by near-surface measurements, which are also discussed. The radiative forcing estimates indicate more warming globally, which is a grave concern.

Keywords: CO_2 pool, Indo-Pacific Warm Pool, ENSO, Global Warming

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Role of distinct oceanic mixed layer processes over meso-scale Eddies in impacting the tropical cyclones over Bay of Bengal

[ABS-05-0198]

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The Bay of Bengal (BoB) is an active region for the formation of the Tropical Cyclones (TCs) and accounts for about 6% of the global annual total number of tropical storms. These TCs occur during the pre-monsoon (March-May) and post-monsoon (October-November) seasons over the BoB. The ocean mixed layer temperature is able to modulate the air-sea interactions between ocean and tropical cyclones, the identified changes/dominant processes in mixed layer heat budget could have notable impact on the cyclone intensity and propagation. In this study, we have conducted an Ocean Mixed Layer Heat budget analysis for distinct TCs over Bay of Bengal. Further we have examined the coherence between distinct ocean mixed layer budget terms and Genesis Potential Parameter (GPP) especially over warm and cold core eddies. Through this analysis, we found that the net heat flux and entrainment terms have high correlations with GPP, with correlation coefficient value of magnitude 0.42 and 0.68 respectively and among all the parameters reported, the entrainment has highest correlation of magnitude 0.68 with GPP. It is interesting to mention that unlike the warm-core eddies the prior response (5 days before the passage of cyclone) between mixed layer terms and GPP is not observed for the case of cold-core eddies. Also the magnitude correlation between distinct terms of mixed layer heat budget analysis and GPP is relatively less for cold-core eddies, compare to warm-core eddies. A notable feature for warm-core eddies is that the net latent heat flux dominates in influencing GPP among the terms that determines net surface heat flux, however, such dominance of net heat flux is not observed for cold core eddies, which infers that the cold core eddy regions are relatively less influential in determining/impacting cyclone life cycle, compared to the warm core eddy regions. Among all the parameters that determines net heat flux, the net latent heat flux showing high response/influence to

GPP. As the latent heat flux is the major pathway between the energy exchanges from ocean to atmosphere, during active cyclone period. The present study could be beneficial in improving the TC models for a better prediction.

Keywords: Keywords: Tropical Cyclones, Bay of Bengal, Mixed layer heat budget, Scatter plots analysis, GPP analysis

Impact of western Pacific cyclone vortices on the frequency of Bay of Bengal cyclogenesis

[ABS-05-0373]

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The link between West North Pacific (WNP) Tropical Cyclones (TCs) and the formation of TCs over the Bay of Bengal (BoB) has been known since the late 1970s. However, the effect of seasonal variability and frequency of WNP TCs on the BoB TCs was not established and is explored in this study. Using various reanalysis and analysis datasets, the Genesis potential index (GPI) of the Bay of Bengal is calculated for the period of 1980-2022. By analysing ocean and atmospheric data, it is found that GPI, which corresponds with the TC frequency (TCF) in the BoB (October- November, ON), decreases (increases) when TCF in WNP (July-September, JAS) increases (decreases). This increase/decrease of TCF in BoB is due to the enhanced/reduced transport of vertically integrated moisture from WNP to BoB during post-monsoon. During the peak cyclogenesis months in the WNP (JAS), the GPI shows higher values and corresponds to increase in TCF. As the density of cyclogenesis increases locally, the amount of consumption of the available moisture content in the atmosphere increases. This leads to decrease in the moisture transport from WNP to BoB in the post monsoon season. The composite difference of anomalous vertically integrated moisture transport of higher number of strong typhoon years (HSTY) and lesser number of strong typhoon (LSTY) years shows the presence of cyclonic circulation over the BoB during the ON months. This signature confirms the increase/decrease in the availability of moisture in the BoB and the corresponding increase/decrease in the TCF during the post monsoon.

Keywords: Bay of Bengal, North western Pacific, Genesis Potential Index, Upper Ocean Heat Content, Tropical Cyclones

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Role of seasonally evolving near-surface salinity stratification on mixed layer heat budget during Summer Monsoon intraseasonal oscillation in the northern Bay of Bengal during 2019

[ABS-05-0334]

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The freshwater flux into the Bay of Bengal (BoB) from continental rivers increases in May and peaks in August-September during the summer monsoon. There is a corresponding variation in the strength of the salinity stratification in the upper ocean. Here we examine the difference in mixed layer temperature (MLT) response to Summer Monsoon Intraseasonal Oscillations (MISO) with respect to seasonally evolving near-surface salinity stratification in the northern BoB using accurate surface fluxes and high-vertical resolution temperature, salinity, and current measurements (~2 m) from a mooring in the northern BoB (17.80°N, 89.5°E) during 2019. Prominent MLT warming and cooling with a range of 1.5°C is observed between suppressed (clear skies, calm winds) and active (cloudy, windy) phases of MISO convection. However, the intraseasonal MLT response to the active phase of a late-season MISO event is minimal compared to MISO events in early summer. We infer this is primarily due to the much smaller contribution from oceanic vertical processes (~6 Wm-2) in late summer 2019, compared to their role in early summer (-15 Wm-2 to -55 Wm-2). During the active phase of the MISO event of late summer 2019, the combined effect of reduced entrainment and weak vertical temperature gradients inhibits near-surface cooling. Conversely, the near-surface salinity stratification and the barrier layer were weak during MISO events in the early summer of 2019. These hydrographic conditions led to enhanced MLT cooling in response to MISO, apparently through a freer turbulent exchange of cool thermocline water with the surface layer.

Keywords: Monsoon intraseasonal oscillation, Bay of Bengal, Mixed layer heat budget, Salinity stratification

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Impact of La Niña and Arctic warming on cold wave conditions in North Indian Region

[ABS-05-0034]

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During the boreal winter season (November to February), the north Indian region encounters recurrent cold wave events, with certain episodes displaying intense severity, leading to significant consequences such as detrimental impacts on human well-being and elevated mortality rates. These intense episodes of cold waves are particularly concerning due to their potential to cause more significant disruptions and challenges. The current study reveals that the intense cold wave events that happen over India is related to La Niña condition and the Arctic warming. The accelerated warming of the Arctic, occurring at a rate four times higher than the global average, has contributed to a notable reduction in sea ice concentration over the Barents-Kara Sea. The loss of sea ice over the Barents-Kara Sea has posed important impact on climate in the recent decades. During La Niña years the Rossby wave induced Arctic warming leads to a reduction in the sea ice concentration over the Barents-Kara Sea. Consequently, anticyclonic circulations develop over the Ural Mountains and thereby leading to blocking conditions which further cause intense cold wave conditions in India especially for the central and northern parts of the country. By establishing this connection, it contributes to the broader understanding of global climate dynamics and how remote factors can influence regional weather patterns. This is further crucial for formulating effective strategies to mitigate their adverse effects on human well-being and mortality rates.

Keywords: La Niña, Arctic warming, Barents- Kara Sea ice loss, intense cold wave, north India

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Biogeochemistry of the Ocean

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Short-term time-series observations of phytoplankton light-absorption and productivity in prydz bay, coastal Antarctica

[ABS-06-0003]

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The optical properties of coastal Antarctic waters are complex due to the dynamic hydrography influenced by meltwater intrusion that changes the nutrient, thermohaline, and optically active substances (OAS) regime. Studies on bio-optical variability and its implications on phytoplankton productivity (PP) are scanty in coastal polar regions. Thus, we conducted time-series measurements (72h @6h interval) of bio-optical properties such as phytoplankton biomass (chlorophyll-a), absorption (aph), and total suspended matter (TSM) concurrently with PP to understand their interplay and variability in relation to the ambient physicochemical settings in the under-sampled Prydz Bay, coastal Antarctica. Results indicated thermohaline stratification in the bay, presumably resulting from the influx of meltwater from the nearby glaciers and low wind activity. The persistent occurrence of sub-surface chlorophyll maximum (SCM) below the stratified layer emphasized the light-acclimatization response of the shade-adapted phytoplankton. Comparatively, more TSM in surface waters than deeper layers indicated glacial melt influence; however, the sunlit depth was relatively stable, indicating less movement of water mass and/or less variability in OAS in the studied location. An inverse relationship between chlorophyll-a and chlorophyll-specific aph (a*ph) manifested the pigment package effect in the prevailing phytoplankton community, implying restrained light-absorption efficiency, which leads to lower PP. Compared to chlorophyll-a, the aph was a better proxy for explaining PP variability. The absence of nutrient limitation was conducive to the growth of microphytoplankton (diatoms). Phytoplankton size classes (micro, nano, and pico) derived using the B/R ratio (aph at Blue (443 nm)/Red (676 nm) region) confirmed the predominance of larger (micro) phytoplankton that are more susceptible to package effect thereby have implications on reduced PP potential of this polar marine ecosystem.

Keywords: Bio-optics, light-absorption, phytoplankton, productivity, Prydz Bay

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Atmospheric deposition of dust and associated nutrients over the Equatorial Indian Ocean

[ABS-06-0134]

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Atmospheric aerosols are potential source of nutrients which can impact surface ocean biogeochemical processes particularly over the remote marine locations and oligotrophic waters. The nutrient data from atmospheric supply is poorly reported from the equatorials Indian Ocean (IO) region. In this study, we present atmospheric nutrients such as reactive nitrogen species (Nitrate, Ammonium, Organic nitrogen), Fe, Mn and Cu concentration along with dust in aerosol sample collected over meridional transect during summer (April-May 2018) and Monsoon (ISM) (June-July 2019) months. A significant spatio-temporal variation of dust is observed during summer (0.6-22.8µg m-3) and monsoon (2.8-25.1 µg/ m-3) months. Dust as well as other nutrient species shows a general north to south decreasing trend. Anthropogenic species like NH4+ and nss-K+ were found below detection limit during monsoon campaign. The fractional solubility of Fe, Mn and Cu were estimated by measuring their concentration in ultrapure water leach which averaged around 0.99%, 31% and 31%, respectively during summer and 0.09%,6%, 16.7%, respectively, during monsoon period. Trace metal enrichment factor and correlation of soluble trace metal with total trace metal, soluble trace metals with total acidic species suggest major influence of anthropogenic emissions as well as atmospheric processing are controlling factor for trace metal fraction solubility during summer in contrast to monsoon. Dry deposition flux of Aeolian dust was estimated for both campaign using Al concentration and relatively higher fluxes were observed for summer (12.6 ± 8.4 mg. m-2. d-1,) and monsoon (8.7 ± 8.4 mg. m-2. d-1) months as compared to model based estimations. Contrastingly, estimated deposition flux of soluble Fe from both campaign displays relatively lower values as compared to model based results, underscores the need for re-evaluation of in biogeochemical models with help of real-time data.

Keywords: Dust, Trace element, Indian Ocean, Nutrients, Organic Nitrogen, Solubility

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Seasonal and spatial variability of biogeochemical constituents in northwestern Bay of Bengal: Biophysical influences and Trophic status of east coast of India.

[ABS-06-0359]

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The coastal seas represent a crucial source of nutrients and energy for aquatic organisms, but also constitute a highly vulnerable ecosystem. Seasonal variations in hydrography and trophic status were investigated along the western shelf of Bay of Bengal (BoB). To gain better understanding of these biogeochemical dynamics and asses the water quality, three research expeditions were conducted in western waters of BoB during pre-monsoon (May 2017), post-monsoon (October 2017) and Monsoon (June 2018). Samples were collected to analyze the water quality parameters such as temperature, salinity, apparent oxygen utilization (AOU), dissolved oxygen (DO), Suspended Particulate Matter (SPM) and Nutrients and chlorophyll-a (chl-a). The trophic Index (TRIX) and Eutrophication index (EI) were computed to describe the environmental status of coastal waters of BoB. Significant spatial & seasonal variation was observed in biogeochemical variables(AOU, Chl-a, DIN)during upwelled & non-upwelled waters along the coast. AOU variability was higher during May 2017 compared to October 2017 and June 2018. The TRIX shows high value (5.8±0.3) during pre-monsoon and moderate (~5) during summer monsoon and post monsoon season. The overall range of TRIX index (5.4-6.1) indicated that the environment was mesotrophic to eutrophic. In addition, the EI values (>1.5) also indicated that the trophic state of east coast of India was moderate to poor. The variation in the biogeochemistry along the coastal waters of the northwestern BoB occurs mainly due to the impact of southwest monsoon and biophysical forces. This study underscores that effect of Indian monsoon flow on biogeochemistry and frequent riverine/atmospheric/upwelling/sewage or industrial (anthropogenic) influx have a significant impact on environmental status of the western coastal waters of BoB.

Keywords: Chlorophyll,Apparent Oxygen Utilization,Nutrients,Upwelling,Bay of Bengal

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Distribution of iodine in the Bay of Bengal and its implication on its Oxygen Minimum Zone

[ABS-06-0127]

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Iodine speciation in marine environments has emerged as a potential tracer of primary productivity, sedimentary inputs, and ocean oxygenation. Inorganic iodine in the marine environment exists primarily as iodate which is a stable form. However, iodide is also observed in surface waters and low-oxygenated waters due to primary productivity in the former and due to the reduction of iodate by microorganisms in the latter. The Bay of Bengal (BoB) also hosts a low oxygen zone, although not as intense as in the Arabian Sea (AS). Iodate is an important electron donor in the anaerobic respiratory pathway, and thus iodate reduction is an important topic to study in low-oxygenated waters. Iodine speciation studies have not been attempted earlier in the BoB and hence this study focuses on the water column iodine speciation within its oxygen minimum zone (OMZ). In general, total iodine and iodide in BoB was observed to be less than that in the AS. Iodide varied between 150 and 220 nM in the surface waters of the BoB. Unlike the AS wherein iodide maxima are observed throughout the OMZ, the subsurface iodide maxima were found only at a few stations in the OMZ of BoB. Total iodine concentration as high as 724 nM was observed in the BoB. Another noteworthy observation was that iodide in the BoB OMZ was not accompanied by the secondary nitrite maxima (SNM) unless iodate was completely reduced to iodide. Since iodide remains in the water column for a long time due to its kinetic stability, we find the presence of iodide maxima but not SNM in the BoB OMZ. Incubation experiments carried out onboard show that the reduction of iodate and nitrate is simultaneous rather than one preceding the other. The experiment also suggests that it is not the amount of available organic matter but rather its residence time that might be the limiting factor for the build-up of secondary nitrite in the BoB. Our study suggests that the presence of iodide can be used to infer the oxygen conditions of the subsurface waters in the BoB.

Keywords: Iodine, Biogeochemistry, Bay of Bengal, Redox, Oxygen minimum zone

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Modelling surface ocean pCO2 in the northern Indian Ocean using advanced machine learning algorithms

[ABS-06-0351]

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The surface ocean partial pressure of carbon dioxide (pCO2) plays a significant role in regulating the Global Carbon Cycle. The spatio-temporal evolution of pCO2 is governed by various physical (upwelling, mixing, entrainment, freshwater influx), and biological (photosynthetic uptake of CO2, respiration, remineralization, etc.) processes. The northern Indian Ocean (NIO) (5°N-30°N, 50°E-100°E), comprising two contrasting basins (Bay of Bengal (BoB) & Arabian Sea (AS)), exhibits diverse physical processes controlling the evolution of surface ocean pCO2. The ocean general circulation models coupled with ecosystem models lack regional observations-driven parameterization of different ocean processes, making prediction of pCO2 using these models challenging. To address this challenge, we have employed several advanced machine learning algorithms such as multi-nonlinear regression (MNR), XGBoost (XGB), random forest-based regression ensemble (RFRE), and, neural network-based Artificial Neuron Network (ANN) to model surface ocean pCO2. The collocated sea surface temperature (SST) and sea surface salinity (SSS) data (from the Surface Ocean Carbon Atlas (SOCAT)), Mixed Layer Depth (MLD) (from a reanalysis product known as Estimating the Circulation and Climate of the Ocean (ECCO)) and surface chlorophyll-a (from a blended chlorophyll-a product (OC-CCI)) were used as independent variables to predict surface ocean pCO2. The validation of machine learning models against the test dataset indicates that RFRE performs best among others with a root mean square difference (RMSD) of 5.69 µatm and a correlation coefficient of 0.99. The comparison of machine learning models predicted pCO2 with in-situ observations available from a RAMA buoy moored at (15°N, 90°E) suggests that the RFRE outperforms other models. Therefore, RFRE based machine learning model may be employed for other regions to model surface ocean pCO2 if sufficient field-measurements are available for model training.

Keywords: North Indian Ocean, Surface Ocean pCO2, SOCAT, Machine Learning Algorithms,Sea Surface Temperature

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Characterising the summer phytoplankton blooms in the North Indian Ocean: Long-term changes and driving forces in the coastal upwelling ecosystems

[ABS-06-0328]

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Coastal upwelling ecosystems are renowned for their exceptional productivity, making their sensitivity to climate change a matter of paramount significance. Recent findings indicate notable shifts in global phytoplankton biomass and the productivity of the oceans. Here we investigate the characteristics of the summer bloom in the North Indian Ocean (NIO), focusing on the upwelling events, long-term changes and the factors driving its occurrences. Distinct changes are identified in the summer phytoplankton bloom in NIO, which warms faster than global oceans. Our analysis finds a decline in Summer (June¿September) Chlorophyll-a (Chl-a) concentration in Arabian Sea (AS: -0.005 mg m-3 yr-1) and Bay of Bengal (BoB: -0.001 mg m-3 yr-1) during the period 1993-2022. Coastal upwelling in NIO shows signs of intensification in the west coast of India. Strong heterogeneity is observed in the case of upwelling events and their trend in the Somali and Oman coast. The Somali upwelling system shows a decline in the Chl-a concentration in the central and an increase in the northern coast in the study period. The driving forces behind these distinct changes are explored, by considering the physical forcing, nutrient availability and climate variability. We observe a cooling in the Somali and Oman coast (-0.05 ℃ yr-1) coinciding with regions showing increased Chl-a concentration. By elucidating the spatio-temporal characteristics, long-term changes and dominant drivers of summer bloom, this study enhances our understanding of the regional ecosystem dynamics and provides valuable information for ecosystem management and conservation.

Keywords: North Indian Ocean, Biogeochemistry,Climate change,Summer Bloom,Upwelling

Biogeochemical dynamics of suspended particulate organic matter in the hydrologically complex continental shelf of southern East China Sea

[ABS-06-0367]

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We investigated biogeochemical characteristics of suspended particles collected at the mid-depth of the 60 m thick upper mixed layer from the inner shelf of the southern East China Sea (ECS) during autumn 2013, when the intrusion of Kuroshio water onto the shelf was intense. We analyzed carbon and nitrogen concentrations (POC and PN) and their stable isotope compositions (δ13C and δ15N), along with hydrographic parameters (temperature, salinity, turbidity and chlorophyll fluorescence), to understand the sources and dynamics of particulate organic matter (POM) in the study area. Our results indicated that the extensive hydrodynamic processes apparently affect biogeochemical characteristics of suspended particles, as revealed by the horizontally mixing POM and the spatial variation of δ15N and molar C/N ratio. Low C/N (2.4 to 6.5) and the less significant correlation between particulate organic carbon (POC) and chlorophyll fluorescence concentrations suggested that POM is dominated by the recently-formed and well-preserved plankton organic matter, consistent with mechanisms controlling δ13C (−24.3 to −21.3 per mil) and δ15N (2.3 to 7.4 per mil) variations. Further, dynamic controls of phytoplankton production and species diversity on δ13C are disentangled by fitting the significant linear correlation between δ13C and POC concentration with the photosynthetic fractionation model. δ15N is largely controlled by the mixing of isotopically different nitrogen sources associated with water masses, in which the importance of biological nitrogen fixation is unfolded, as evidenced from the relatively depleted δ15N and significant negative correlation between δ15N and water temperature. This result provides some insights that biological nitrogen fixation play an important role in supporting the marine production in the hydrologically complex ECS. In addition, wide ranges of both δ13C and δ15N of marine productivity-derived POM reflects the dynamic nature of carbon and nitrogen cycling, suggesting that care should be taken when assuming endmember values for marine plankton in the shelf seas.

Keywords: Particulate organic matter; Hydrographic parameters; Carbon and nitrogen stable isotopes; East China Sea

Transformation of particulate matter while sinking through the Oxygen Minimum Zone of the Eastern Arabian Sea

[ABS-06-0104]

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The degradation of particulate organic matter in the ocean plays an important role in the carbon cycle and sustenance of oxygen minimum zones (OMZs). The organic matter produced in the euphotic zone undergoes recycling while sinking through the water column and only a small fraction rains out to the seabed carrying organic carbon, nutrients and minerals along with it. The sinking flux is formed by aggregation of fragments of decaying organisms, faecal pellets and extracellular polysaccharides, and are degraded and consumed by a large community of heterotrophic bacteria that are attached to the particle surfaces. In the present study, suspended particulate matter (SPM) was collected at three stations (G5: 27m, G12E: 668m and G14B: 1484m) in the Eastern Arabian Sea covering both oxic and suboxic water column by using large volume McLane insitu filtration unit. These samples are analysed for particulate organic carbon and nitrogen (POC and PN) contents and their isotopic ratios, and phytoplankton marker pigments, alkanes, fatty acids and sterols. The POC and PN contents decreased within the upper 60 m water column while the POC/PN ratio increased in the deeper waters due to preferential removal of nitrogen. The δ15N values varied in the range (+2.7 to +6.4¿) with higher values in the surface and suboxic zones, whereas δ13C values were high in the euphotic zone and depleted (up to -24¿) with depth. n-alkanes showed higher concentrations in the euphotic zone with no odd-even preferences. C16:0 was the dominant fatty acid at all the depths followed by C18:0 reflecting the dominance of diatoms followed by dinoflagellates. Cholesterol, brassicasterol, stigmasterol and β-sitosterol were present in the SPM samples with higher concentration in the upper water column. The concentration of phytoplankton marker pigments was high in the euphotic zone whereas the degraded pigments (pheophorbide a and pheophytin a) were present in the suboxic waters. The scanning

electron microscopic analysis showed the presence of diatoms, coccolithophores, radiolarians, silicoflagellates, foraminifera etc. in the SPM samples with decreasing abundance in deeper waters. Our study clearly showed significant degradation of organic matter within the water column and also the preservation efficiencies of various biomarkers.

Keywords: suspended particulate matter, biomarkers, sterols, fatty acid, Eastern Arabian Sea

Preliminary study on quantification and characterisation of microplastics in surface water, bottom sediments and beach sediments of Pondicherry coast, South India

[ABS-06-0247]

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The current study gives an overview of the quantification and characterisation of microplastics in the surface water, bottom sediments and beach sediments of the entire Pondicherry coast. This is a preliminary investigation as surface water and bottom sediments are studied for the first time. A total of nine coastal stations and two river stations are studied covering a stretch of around 40 km across the coast. The bottom sediments are collected in three different depths (5m, 10m, 15m) to check the spatial variation. Samples were analysed quantitatively and qualitatively. The average number of microplastics in surface water and bottom sediments of Puducherry is 1.14 ×103 particles/km² and 14.58 particles/kg. In beach sediment, the average microplastics is found to be 9.629 ±3.03 particles/kg. the spatial variation based on depth gave the insight that the average Microplastics decrease with the increase of depth i.e. at 5m -118.88 particles/kg > 10m- 94.44 particles/kg >15m- 73.33 particles/kg. The samples were analysed for the characterisation of polymer type by Raman Spectroscopy. Out of the potential microplastic samples analysed, the type of polymers extensively prevailing are Polypropylene (PP), Polyethylene (PE), Polyvinyl chloride (PVC), Ethylene propylene copolymer, Ethylene vinyl acetate copolymer, LDPE, Polyethylenterephtalate. Polypropylene and polyethylene are dominant in sea surface water whereas Low Density Polyethylene (LDPE) and PVC are dominant in bottom sediments, again PP and PE are mostly found polymer type in beach sediments. Based on the shape of Microplastics, fibres hold a large amount 77.04% of the total Microplastics found in Surface water, 75.08% of fibres in bottom sediments and 96.73% in beach sediments. This is concluded that microplastics are mostly contributed by excessive use of nets, ropes, urban runoff and the other major contributor is may be tourism activity.

Keywords: Microplastics, Surface Water, Bottom Sediments, Raman Spectroscopy, Polypropylene

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Nutrient variability along the salinity gradient: A case study of Rushikulya river, India

[ABS-06-0310]

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The Rushikulya River is a coastal plain estuary known for sand spit formation, which supports Olive Ridley rookeries. The coast experiences a semidiurnal tidal range of up to 2.1 m, consequently evolving a prominent salinity gradient along the estuarine length. The present study assesses the variability of nutrients along the salinity gradient. Physical and biogeochemical parameters of the surface waters e.g. air and water temperatures (AT &WT), salinity, dissolved oxygen (DO), biological oxygen demands (BOD), primary productivity (PP), chlorophyll-a (Chl-a), nitrite (NO2-), nitrate (NO3-), ammonia (NH4+), dissolved inorganic nitrogen (DIN), phosphate (PO43-), silicate (SiO44-) were measured during the high and low tidal phase in June 2022 (premonsoon). Samples were collected from four different sectors i.e., riverine (0.5), oligohaline (0.5-5), mesohaline (5-18), and polyhaline (18-30) zones. The results indicate that salinity increases during the high tides and decreases progressively towards the upstream during both tidal phases. DO was high during low tide and low during high tide and inversely correlated with salinity. NO2-, NO3- are positively correlated with salinity. NH4+ and PO43- are negatively correlated with salinity during low tide but the trend reversed during high tide. SiO4- exhibited a negative correlation with salinity irrespective of the tidal condition. PP was negatively correlated with chlorophyll and positively correlated with NO2-, NO3-. The significant variation in the physical and biogeochemical parameters could be attributed to nonpoint sources such as adjacent agricultural runoff. Stoichiometry of nutrients suggests that the estuarine productivity is not limited by any of the nutrients as their concentrations are much above the critical level. The nutrient regeneration rate is found to be higher than the nutrient uptake rate irrespective of location and tidal condition suggesting that the estuarine ecosystem is healthy and balanced.

Keywords: Salinity gradient,Nutrients,Primary Productivity,Estuary,Rushikulya

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An insight into physico-chemical water quality parameters of Visakhapatnam coast, Bay of Bengal

[ABS-06-0311]

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Marine pollution is a global issue that affects both developed and developing countries. Since the industrial revolution and with increased urbanisation, Indian coastal waters have become polluted gradually, not just from shipping but also from the discharge of sewage, industrial waste, and agricultural runoff. Visakhapatnam is a coastal city on India's Eastern seaboard surrounded by number of suburban/satellite townships. Long stretches of Visakhapatnam sandy beaches are the most attractive tourist spots. The present study on Visakhapatnam coastal water quality evaluated the anthropogenic impact. Beach/shore water samples were collected from 13 numbers of stations i.e. VC1 to VC13 during February 2023. The results revealed thatSea surface water temperature varied from 24 to 29 °C, Total suspended solids (TSS) 0.27 to 0.61 mg/l, pH 7.73 to 8.12, Salinity (PSU) 24 to 31.50. The Lowest value of DO (2.60 mg/l), pH (7.73) and salinity (24 PSU) were recorded at VC-11, 13 and VC-9 respectively. Higher concentrations of NO3-N (14.15 µM), TN (169 µM) in VC-1, BOD (9.80 mg/l), NH4+-N (34.11 µM) and Chlorophyll-a (Chl-a, 7.53 mg/m3) in VC-11 and PO4-P (4.75 µM) in VC-13 were recorded.The salinity, pH and DO were negatively correlated with Chl-a , whereas BOD and TSS showed the positive correlation with it. Thus it is evident that the beach water was of very poor quality due to anthropogenic activities and discharge of untreated sewage in to the marine ecosystem. The findings are crucial for establishing baseline conditions for comparative research with other ecosystems in order to improve environmental conservation and management.

Keywords: Water quality, Physico-chemical, Coastal water, Salinity, Chlorophyll-a, Marine pollution

Variations in coastal water quality of Thondi coast, southeast coast of India

[ABS-06-0330]

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The present study was carried out to determine physico-chemical characteristics of Thondi Coast, Palk Bay for a period of six months from December 2021 to May 2022. In the present study, temperature and salinity were not varied significantly. But the pH concentration was observed between 7 to pH 8.7. The electric conductivity (EC) varied from 13.8 to 28.46 S/m. The total dissolved solids (TDS) varied from 6.49 to 14.4 mg/l. The dissolved oxygen (DO) varied from 2.4 to 5.2 ml/l during May (summer) and December (monsoon) respectively. The biological oxygen demand (BOD) was 0.1 mg/l during May (summer) at station 2 and 3.6 mg/l during December (monsoon). Nutrients such as nitrite slightly varied between stations while the Nitrate (NO_3^-) fluctuated from 0.021 µmol/l to 6.947 µmol/l during March and December respectively. The inorganic phosphate varied from 0.005 to 1.65 µmol/l while the total phosphorous varied from 0.004 to 2.347 µmol/l. The reactive silicate varied from 0.04 to 1.95 µmol/l. But the ammonia (NH_3) varied from 0.001 to 0.855 µmol/l. Physico-chemical parameters in Thondi coast were not significantly changed despite the study area receiving huge quantity sewage disposal and other anthropogenic activities.

Keywords: Water quality, Palk Bay, Thondi coast, BOD, Ammonia

Synergy between observational and modelling estimates on Indian Ocean acidification
[ABS-06-0013]

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Global Oceans absorb ~ 30% of the human-made carbon dioxide (CO2) gas emitted due to increased fossil fuel burning, cement production, and land-use change. Without this ocean's 'natural' sink, the build-up of atmospheric CO2 would be more extensive by another 30%, accelerating global warming. Therefore, the sequestration offered by the global oceans is critical in modern-day climate and climate change. However, this comes with a penalty that the dissolved CO2 increases the free H+ ions in the ocean turning ocean into acidic conditions. A global surface ocean pH up to 65oN for 1985-2018 is compared between two data products: output from a bottom-up approach, process-based biogeochemistry model (OTTM), and a neural network-based gap-filled data (SODA-ETHZ). The basin-wide mean and biases are estimated and compared to the seasonal cycle, interannual variability, and long-term trend among these two data products for nine oceanic regions from the tropics, mid-latitudes, and southern oceans. OTTM has a global acidic offset of 0.022 pH units compared to SODA-ETHZ. The seasonal mean and amplitude are 8.086 ± 0.007 and 8.063 ± 0.008 in SODA-ETHZ and OTTM, respectively, with the tropical Pacific marking the most acidic ocean in both the data sets. OTTM has comparatively more significant interannual variability (±0.0017) as compared to SODA-ETHZ (±0.0011), with the most considerable variability found in the tropical Indian Ocean in both the data products (±0.0018, ±0.0028 for SODA-ETHZ, OTTM respectively). OTTM indicates an enhanced global ocean acidification trend by 11.32 ± 7.61 % compared to SODA-ETHZ with -0.056 ± 0.006 and -0.050 ± 0.003 pH trends in 1985-2018, respectively. The agreement in long-term mean, seasonal variability, and trends indicate the capacity of bottom-up and top-down approaches to constrain contemporary global ocean acidification reasonably. However, regional interannual variability lacks a significant correlation among these data products, meaning requirements for sustained observational efforts to resolve those subtle variabilities in models. Global Ocean acidification (pH) from a bottom-up process-based model output is compared with gap-filled data by a machine-learning approach.

Keywords: Acidification, Machine Learning, bottom-up models, intercomparison, trend, variability

Elemental stoichiometry in the tropical Indian Ocean and their predictors

[ABS-06-0495]

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Marine primary productivity plays a key role in regulating the global carbon cycling through biological pump by reducing the atmospheric carbon dioxide. However, the productivity of different phytoplankton species, as well as their distribution and growths in the marine ecosystem, is directly dependent upon the nutrient availability and their stoichiometry (i.e., the Redfield ratio). Recent studies, based on sparse data collected from different oceanic basins, suggest that the elemental ratios of these nutrients deviate from the canonical Redfield ratio and follow a strong latitudinal pattern. However, findings are highly skewed toward the studied basins, whereas the data from the Indian Ocean is relatively lacking. We analyzed a large dataset (from 50 locations) of nutrients in both the inorganic and organic pools of dissolved and particulate matter in the northern Indian Ocean (the Arabian Sea and the Bay of Bengal). This study aims to explore the variations in elemental stoichiometry over space and time as well as to understand the role of biogeochemical processes and hydrographic factors. Our results suggest that both the inorganic and organic pools of dissolved and particulate matter show variable nutrient ratios in the water column with high seasonality. The mean value of C:N:P ratios in the organic particulates in the top (~189:28:1), subsurface (~251:31:1), and deep (~409:39:1) layers were significantly higher than the Redfield ratio and also surprisingly higher than the value observed for low latitudinal regions. Whereas, the dissolved inorganic N:P ratio increases from the top to the deeper layer and shows a covarying trend with the concentration of dissolved inorganic N and P in the water column. Interestingly, the dissolved inorganic N:P ratio was lower than the Redfield ratio throughout the sampling periods indicating the biological productivity in the Indian Ocean is limited by N than P. Further, the model analysis (GAM) also supports the higher deviance value explained by N than P, where sea surface temperature seems to be playing a dominating role. These observations provide a valuable understanding of nutrient

availability governing the productivity in the Indian Ocean, therefore making a valuable contribution to the sustainable development of the productive ocean and food security.

Keywords: Indian Ocean, Ocean biogeochemistry, productivity, Redfield ratio, major nutrients

Dynamics of nitrous oxide in the southeastern Arabian Sea

[ABS-06-0421]

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This study examined the seasonal variations of dissolved nitrous oxide (N2O) in the southeastern Arabian Sea to identify the factors controlling the release and emission of this critical greenhouse gas. Time-series measurements (monthly) of nitrous oxide and associated biogeochemical variables were undertaken at 3 locations across a coastal transect off Kochi, southwest coast of India, from August 2020 to December 2021, and continuous measurement for 36 hours at a single site off Kochi (15m water depth) at 3-hour intervals (June 2021).The southwest monsoon period (SWM) brought drastic changes in the regional hydrography through the incursion of hypoxic waters due to coastal upwelling, which increased N2O concentrations (8-89nM) substantially. The N2O concentration was relatively lower during the non-upwelling period (2-27nM), and the hypoxic water column during the upwelling period (8-89 nM) showed a significant accumulation of N2O. The significant positive correlations of N2O with apparent oxygen utilisation (AOU), the sum of dissolved nitrate and nitrite (NO2-+NO3-), excess N2O (ΔN2O) and a negative correlation with dissolved oxygen during the non-upwelling period evidence nitrification as the major process. However, N2O showed a significant negative correlation with dissolved nitrite under hypoxia (DO < 25 μM) and did not display any correlation with NO2-+NO3-during SWM, which suggests the possibility of nitrifier-denitrification as an active process during hypoxia. This could be a plausible explanation for the N2O enrichment in the present study region.

Keywords: Upwelling, hypoxia, greenhouse gases, nitrification

Paleoproductivity, terrigenous input, and redox condition of the southeastern Arabian Sea during past 13 kyr

[ABS-06-0462]

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Changes in oxygen concentration of the bottom water limits carbon cycle. Sedimentological, geochemical and elemental proxies were analyzed to assess the past variation in the productivity, terrigenous input and redox condition of the southeastern Arabian Sea during last ~13.5 kyr. Terrigenous indicators of major elements such as Al, Fe and Ti and their mass accumulation rates (MARs) show higher terrigenous input during the late Glacial and early Holocene period. Productivity proxies, including OC and CaCO3 contents and their MARs, and paleoproductivity recorded lower productivity during the late Glacial and early Holocene, whereas higher productivity during the mid and late Holocene periods. Our results show significant changes in oxygenation conditions in response to changes in ocean circulation. The present study revealed that bottom water in the southeastern Arabian Sea was suboxic during late Glacial and early Holocene than the mid to late Holocene period. Enrichment factors of the trace element like Zn and Cu are 1.3 and 1.7 respectively, indicating that authigenic enrichment of trace elements is very less. However, V does not show any trend which suggests that the southeastern Arabian Sea has likely never attained the anoxic condition during the past ~13.5 kyr.

Keywords: Paleoproductivity, terrigenous input, redox condition, southeastern Arabian Sea

Mechanisms and drivers controlling sea-surface pCO2 variability in the Northern and southern Bay of Bengal

[ABS-06-0374]

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The northern and southern (above and below 15°N) of the Bay of Bengal (N-BoB and S-BoB) exhibit contrasting physical and associated biogeochemical dynamics due to high freshwater influx from rivers, monsoon precipitation, deposition of aerosols from anthropogenic sources, etc. Therefore, we hypothesize that the seasonality and magnitude of the sea-surface partial pressure of Carbon Dioxide (pCO2) significantly differ in these regions. This study uses a regional, high-resolution coupled physical-biogeochemical model simulated outputs (2006-2017) to understand the mechanisms and drivers modulating the sea-surface pCO2 in N-BoB and S-BoB. The difference in the rate of increase of pCO2 (3.97 µatm yr-1 for N-BoB and 3.88 µatm yr-1 for S-BoB) is approximately 0.1 µatm yr-1. Our analysis indicates that among the four primary drivers (SST (Sea Surface Temperature), FW (Freshwater), DIC (salinity normalized Dissolved Inorganic Carbon), and TA (salinity normalized Total Alkalinity)) controlling seasonality of sea-surface pCO2 in the ocean, SST is the main driver controlling pCO2 variability in both regions. SST primarily induces pCO2 anomalies in N-BoB and S-BoB, although DIC strongly counters it. The effect of TA is negligible in both regions, but the FW has a strong control on the pCO2 in the N-BoB during the post-monsoon seasons. The winter-monsoon (DJF) has the lowest pCO2 anomalies driven by the lowering of the SST in both regions. The strong stratification in the N-BoB inhibits mixing, which reduces the nutrient availability in the surface ocean and weakens the biological pump. The reduced biological influence results in higher pCO2 levels. However, the high retention time of fresher surface waters reduces pCO2 in the N-BoB. This study shows that the stratification reduces the pCO2 by approximately 10 µatm in the N-BoB. The stratification has strong control in reducing sea-surface pCO2 in the N-BoB than the S-BoB.

Keywords: Bay of Bengal,sea-surface pCO2,ROMS,Stratification,Freshwater

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Zooplankton trophodynamics revealed by stable isotope analysis

[ABS-06-0399]

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This study was the first attempt in the eastern Arabian Sea (EAS) to understand zooplankton trophodynamics using stable isotope analysis (SIA). Variations in diet preferences and trophic positions of major zooplankton groups (copepods, decapods, ostracods, amphipods & chaetognaths) were elucidated using carbon (C) and nitrogen (N) stable isotope ratios from coastal waters during peak and late summer monsoon (PSM & LSM). Mean δ13CPOC did not vary between phases (PSM: -21.73 ±2.19 & LSM: -21.25 ±2.51) and showed a major contribution of marine organic matter at most of the locations except at 12°N (-28.06) where terrestrial inputs were noticed during PSM. POC: Chla (<200) and C: N (<13) also supported these observations and showed a major contribution of marine phytoplankton during both phases. To further classify sources, correlations between δ13CPOC and δ15NPN within mixed layers were considered that indicated the contribution of a single source during PSM and multiple sources during the LSM. Variations observed in chlorophyll a (Chla) concentrations and phytoplankton population also confirmed these observations as upwelling induced high Chla (4.01 ±3.22 μg l-1) and micro-phytoplankton abundance (~93.09%) showed the contribution of a single source to the POC during PSM; while decreased Chla concentrations (1.69 ±1.9 μg l-1) and enhanced population of nano & pico-phytoplankton (21.47% & 36.27%) due to weakening of upwelling showed the contribution of multiple sources to the POC during LSM. Relative trophic positions (RTPs) of major zooplankton groups were calculated by considering δ15N of POM (5.21 to 12.87¿) as the base of the food chain. Slightly higher RTPs were observed during PSM (>1.5) that showed herbivorous diet preferences whereas lower RTPs (<1.5) during the LSM were due to multiple food preferences and were not necessarily represented by POM. This resulted in the presence of a shorter food chain during PSM and a longer, complex food web during the LSM. Spatiotemporal variations in the intensity of upwelling resulted in altering the length and complexity of the food web.

C & N stable isotope ratios were used to improve our understanding of the planktonic food web and can be further utilized at higher trophic levels.

Keywords: stable isotopes, mesozooplankton, particulate organic matter, eastern Arabian Sea, summer monsoon

Spatial variability in the mass and sources of sinking fluxes along the east coast of India

[ABS-06-0382]

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The Bay of Bengal receives fluvial fluxes from the major rivers, such as Ganges, Brahmaputra, Godavari, and Mahanadi, resulting in the formation of Bengal fan. In order to examine the role of different rivers in the transport of sediments to the coastal Bay of Bengal, three sediment traps were deployed at 350 m depth from the surface off Godavari, and Mahanadi River mouths and off Visakhapatnam, where no river opened. The influence of circulation is variable along the east coast of India due to seasonal reversal in the East India Coastal Current (EICC) that redistributes the fluvial sediments along the coast. The lower salinity (strong stratification) is observed off Mahanadi compared to off Godavari due to the higher influence of freshwater transport from the Ganges in the north. Despite low salinity and high influence from Ganges in the northern coastal Bay of Bengal, lower mass flux of sediment was observed off Mahanadi (2.8 mg/m2/d) compared to off the Godavari River mouth (9.4 mg/m2/d). The contribution of carbon and nitrogen to the mass flux was higher off Mahanadi (6.0% and 0.9% respectively) than off Godavari (3% and 0.4% respectively) suggesting that northern Bay is receiving higher organic matter than south. The C:N ratios were lower than Redfield ratio off Mahanadi (3.2) than off Godavari (8.6) suggesting that either sources of organic matter may be different or modification of organic matter. The isotopic composition of nitrogen (δ15NSed) of sediment displayed large variability at all location (-1.8 to 9.5) with the mean value being lower off Mahanadi (3.3¿) compared to off Godavari (5.7). The δ15NSed of sediment displayed linear relationship with C/N ratio suggesting that bacterial decomposition of organic matter brought from the rivers lead to enrichment of δ15NSed. This study suggests that river- borne organic matter supports ecosystem in the coastal Bay of Bengal through microbial loop than hitherto hypothesized as recalcitrant.

Keywords: Mass flux, Sediments, Bay of Bengal, C/N Ratio, δ15Nsed

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Spatial distribution of nutrient dynamics of coastal water along Ennore creek Chennai, India.

[ABS-06-0368]

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Industrialization and urbanization of the coastal region often lead to decreased coastal resources and natural defence structures. The increasing pollution levels over the coastal water are impacting the coastal ecosystem. One of the major environmental problems caused by eutrophication in the aquatic environment is the formation of algal blooms, which reduces oxygen levels and eventually leads to the extinction of marine flora and fauna. The present study was therefore undertaken to provide much-needed information on the water quality parameters (Nutrient dynamics) in the Ennore Creek (EC) and coastal water, Chennai. The sampling sites were selected based on the non-point and points sources of discharge from critical industries in the Ennore region. The nutrients in EC showed enrichment of $NO3^-$, NH4+ and PO43- during the study period. In both creek and coastal water, $NO3^-$ and NH4+ contribute significantly more in dissolved inorganic nitrogen. In EC, $NO2^-$ estimated was 12.4 ± 1.4 µmol/L, whereas, in coastal water, it was 0.7 ± 0.4 µmol/L, indicating high-level eutrophic nature with inorganic nitrogen present in the water. In the present study, the $NO3^-$ value was 57.4 ± 6.1 µmol/L in EC and 11.3 ± 1.5 µmol/L in the coastal water. PO43- value in EC was 14.4 ± 2.8 µmol/L while the coastal water was 0.7 ± 0.2 µmol/L. In EC, NH4+ recorded was 70.4 ± 4.9 µmol/L, whereas, in the coastal water, it was 7.7 ± 0.7 µmol/L. High levels of both $NO3^-$ and PO43- can lead to eutrophication, ultimately reducing dissolved oxygen levels in the water. The high concentration of nutrients may be due to the discharge of large quantities of domestic sewage. Due to the ongoing discharge of domestic sewage and industrial effluent, the concentrations of nutrients vary both diurnal and spatial in the creek and coastal water. The nutrient level in EC has increased due to various point and non-point sources of discharge. The creeks and estuaries serve as a breeding habitat for aquatic animals. It is essential to regulate these actions to recover our marine bodies.

Keywords: Nutrients, Ennore Creek, Coastal water, Eutrophication, Urbanization

Green Noctiluca bloom in the northeastern Arabian Sea: A comprehensive review

[ABS-06-0426]

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The Arabian Sea is one of the most productive regions of the world ocean that experiences large-scale algal blooms during the winter monsoon period. Convective mixing under the winter monsoon recharging the water column with nutrients, and atmospheric deposition of external nutrients are the major factors that fuel the bloom. Dramatically, a succession of the dominant species has been observed since the 2000s, from multispecies diatom bloom to mixed bloom of diatom and dinoflagellate (dominated by green Noctiluca scintillans). Green N. scintillans is a mixotroph, although not toxic, known to cause water quality deterioration, fish mass mortality, and ecosystem disruption in the coastal waters. The surpassing of N. scintillans¿ dominance over diatoms as bloom-forming species is still under investigation. The interplay of nutrient stoichiometry is advocated as the most plausible factor that causes the shifting of diatom to N. scintillans during the annual cycle of bloom in the northeastern Arabian Sea. A thorough perusal of available literature revealed the impact of N. scintillans on the food web is very less studied in comparison to the in situ and remote sensing based spatio-temporal dynamics. Green N. scintillans is not a preferred food source for the copepods, which are major phytoplankton consumers. On the other hand, they are consumed by jellyfish and salps and thereby pose the risk of large quantities of carbon transfer bypassing the conventional food chain pathway that leads to fish. This study provides a detailed overview and analysis of the N. scintillans research in the northeastern Arabian Sea and the way forward to fill in the knowledge gaps.

Keywords: Water Quality; Diatom; Mixing; Chlorophyll; Nutrient

Observed short-term hydrographic and biogeochemical changes in the Subtropical and Polar Fronts during the austral summer of 2011

[ABS-06-0274]

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A study comparing the short-term hydrographic and biogeochemical changes in the Polar Front (PF) and the Subtropical Front (STF) of the Indian Ocean sector of the Southern Ocean has been carried out using the multidisciplinary time-series (72 hrs) observations collected every 3 hrs interval from the STF and PF during the austral summer 2011. The Sea Surface Temperature (SST) at the PF region was found to be about 4°C and that at the STF was about 16°C. The diurnal variability of the SST was not prominent in both fronts. The mixed layer depth (MLD) at PF was found at a depth of nearly 60m and that at STF was at a depth of 40 m and the variability of MLD with respect to was significant in both the fronts. Surface chlorophyll (Chl) - a of the PF was higher (> 0.5 mg/m3) than the STF (<0.4 mg/m3). The presence of strong subsurface chlorophyll maximum (SCM) was found at about 75 meters deep in the PF whereas it was at a much shallow depth in the STF. The strong pycnocline and resultant stratification may be one of the possible causes for the shallow SCM at STF. The role of light on the SCM variability was also discussed. In this study, the time variability (3 to 6 hrs) of the hydrography and its impact on biogeochemical changes of two contrasting and dynamic environments like STF and PF were discussed in detail.

Keywords: Fronts, Mixed layer depth, Chlorophyll, Southern ocean

Understanding the impact of coastal currents on the biogeochemical dynamics along the eastern coast of India using high-resolution modelling

[ABS-06-0321]

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The dynamics along the eastern coast of India are dominated by the poleward flowing Western Boundary Current (WBC) during the pre-summer monsoon and the equatorward flowing East Indian Coastal Current (EICC) during the winter monsoon. This results in a current-driven upwelling along the eastern Indian coastline during March-May and wind-driven upwelling during June-September. During winter monsoon, the EICC associated coastally trapped Kelvin waves induces downwelling along the coast. These seasonal features impact the coastal biogeochemical dynamics. In this study, we have used a high-resolution (1/20°) model MITgcm integrated with DIC package on a climatological scale to simulate the seasonal characteristics of biogeochemical components. During upwelling, the DIC enriched subsurface waters entrain to the surface thereby decreasing pH at the surface. The WBC further advects these waters towards the head bay region. In the head bay, the discharge of glacial rivers reaches its maximum during August-September, and these rivers tend to be relatively basic than the peninsular rivers. The EICC further brings this basic freshwater till eastern Sri Lankan coast, thereby increasing the pH of the coastal waters. The surface biological production is observed to be maximum in the head bay region, especially during the summer monsoon due to nutrients and sediments brought by the riverine discharge. This is also observed along the peninsular river mouths. Like pH signature, the oxic waters in these high productive regions are transported from head bay equatorward along the coast during winter monsoon due to the propagation of EICC. Phosphate concentration is observed to be maximum during upwelling season when the nutricline shoals to the surface, fueling higher productivity. However, downwelling during October-March causes phosphate to become a limiting agent at the surface. The Sri Lankan dome, driven by oceanic

currents and local bathymetry results into high surface phosphate. Along with other nutrients, it results in slight increase in productivity in this region during July-September. Additionally, we also investigated the deepwater transports of carbon caused by undercurrents. Seasonal studies of biogeochemical variables reveal coastal ecosystem dynamics and the interplay between physical processes, nutrient availability, and biological productivity.

Keywords: Ocean biogeochemistry, carbon cycle, coastal dynamics, ecosystem modelling, MITgcm

Cross-frontal variability of phytoplanktonic production in the Indian Sector of the Southern Ocean during the austral summer (2010-2018)

[ABS-06-0089]

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The sequestration of carbon by phytoplankton through photosynthesis plays a major role in the Oceanic environment as a source of food to the upper trophic level and also as a major contributor to atmospheric CO2 sink. During the last decade, the rate of photosynthesis or the primary productivity (PP) by phytoplankton in the Indian Sector of the Southern Ocean (ISSO) varied greatly with latitudes, owing to its extreme environmental conditions and variable physiochemical settings across the fronts. The PP showed a decreasing trend in the frontal region from Sub-Tropical Front (STF) towards the Polar Front (PF). Among the fronts, the Sub-Antarctic Front (SAF) was the most productive (338.86 ± 145.42 mg C m-2 d-1), while the lowest productivity was observed at Polar Front-2 (72.51 ± 69.27 mg C m-2 d-1). The high PP at SAF compared to that of STF, despite low surface chlorophyll a, as well as integrated water column chlorophyll might be due to photoinhibition experienced by the former front due to high Photosynthetically Active Radiation (PAR) in this region. The low production at PF-2 can be attributed to the deepening of the Mixed Layer Depth (MLD) driven by strong wind experienced in this region. As compared to the fronts (239.66 ± 93.04 mg C m-2 d-1), the coastal Antarctic region was more productive (388.50 ± 220.98 mg C m-2 d-1), which might be due to the high concentration of silicate that facilitated the growth of larger diatoms which were adapted to the environmental condition of this area. The C:N ratio showed a decreasing trend from the global average (6.6), towards higher latitudes indicating the higher efficacy of coastal regions in terms of carbon export. In ISSO, light availability, vertical mixing, and nutrient (macro and micro) availability play a crucial role in influencing the physiological condition of phytoplankton, thus their efficacy in carbon sequestration.

Keywords: Primary Production, Indian Sector of Southern Ocean, Phytoplankton Physiology, Carbon Export

Seasonal variation of water quality parameters and its influence on primary productivity over Ennore coastal region.

[ABS-06-0369]

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Chennai City is the fourth largest metropolis in India, and the coastal region of this city is a typical example of sewage and severe pollution. The current study focuses on the influence of water quality parameters on primary productivity in different seasons over a region. The samples were obtained in different seasons (Southwest monsoon, pre-monsoon, and post-monsoon). The samples were chosen based on key industry discharge points in the Ennore region. We collected surface water samples and used a YSI 2030 DO metre to measure Temperature (°C), pH, dissolved oxygen (mgL-1), and salinity (ppt). Total Suspended Solids (mgL-1) and nutrients were analysed per the standard method. The seasonal variation of primary productivity has been studied using the Chlorophyll-a (mgm-3) pigment data from Moderate Resolution Imaging Spectroradiometer. Various factors affect productivity, including the availability of DO, light, nutrients, wind, temperature and turbidity. The nutrient availability associated with upwelling and vertical mixing modulates the seasonal variation of Chl-a in the southwestern Bay of Bengal. The pH measured shows the acceptable range (7.6-8.2), the standard for aquatic life. Other than that, is a range of DO observed in the Ennore region, where Oct has the highest concentrations, followed by Feb and Nov. Another critical parameter is temperature; in-situ, observation shows the lowest in the post-monsoon season compared with the other season. Light is one of the limiting factors in Bay of Bengal water due to the riverine discharge, so the TSS value indirectly shows the availability of light on the surface of coastal water. The maximum TSS was recorded in Aug (40.3 mg/L) and Nov (40.1 mg/L), and where minimum during Oct (18.6 mg/L). These physical water quality parameters were compared with the Chl-a data to understand the favourable condition for their growth. The Chl-a, data shows a high spatial distribution of blooms in Nov, followed by Oct and Aug. In Nov, blooms can be seen inside the creek and the coastal water, Chl-a noticed>9.0mgm-3. The high variability of Chl-a was observed in the post-monsoon compared to the other seasons in the Ennore region.

Keywords: Primary productivity, Total suspended solids, Ennore estuary, Creek, DO.

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Studying the role of nutrient limitation on plankton biomass over the Bay of Bengal using an ecosystem model (NEMURO)

[ABS-06-0052]

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Factors regulating marine production have broad societal interest especially understanding the role of nutrients in determining the growth of phytoplankton that regulates the primary production of the oceans. We need certain tools to study the variability of dominant nutrient limitation and its influence on marine production. A 1-D coupled physical-biogeochemical model based on the North Pacific Ecosystem Model for Understanding Regional Oceanography (NEMURO) with nitrogen and silicon cycles is adapted for the Bay of Bengal environment. Model parameters were tuned for the Bay of Bengal. The model is implemented to investigate the role of nitrogen (nitrate + ammonium) versus silicate limitation on plankton biomass. The NEMURO model has 13 components of the ecosystem such as two functional groups of phytoplankton (PS, PL), three groups of zooplankton (ZS, ZL), dissolved and particulate organic matter, and sinking particle fluxes. The seasonal cycle of plankton biomass is well simulated by the model along bio-Argos (during a period from 2016 to 2018) over Bay of bengal. Based on the spatial distribution of bio-Argos we divided them into two groups (East and West). On the surface of the West group, the magnitude of PL (eg., Diatoms) is greater than that of PS (eg., flagellates) throughout the year. The ZS (eg., zooflagellates) and ZP (eg., copepods) follow the seasonal pattern of PS and PL. However on the East group of bio-argos seasonal fluctuations are noticed in both PS and PL. This study further discusses the dominant nutrient contribution to the production.

Keywords: nutrient limitation, plankton biomass, Bay of bengal, bio-Argos, ecosystem model

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Application of Bio-Argo float in understanding denitrification in the northern Indian Ocean.

[ABS-06-0162]

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N* is a tracer introduced by Gruber and Sarmiento to study the effect of denitrification and nitrogen fixation in the ocean in 1997. It uses phosphate to correct the nitrate portion of its distribution due to nitrification reaction. N* describes the combined effect of denitrification and nitrogen fixation or remineralisation of the nitrogen-rich organic compound. This process is spatially well separated and can be understood whether the process is from the signals either coming from one or from different processes. N*=N-16. P +2.9 µmol/kg Here N* is the nitrate concentration in µmol/kg, and P is the concentration of the phosphate in µmol/kg. Distribution of N* has been analysed for the northern Indian Ocean, both the Arabian Sea (AS) and Bay of Bengal (BoB), using data derived from two Bio-Argo floats. The average value of N* at denitrification depths is ~ -12 µmol/kg and ~-5 µmol/kg in AS and BoB, respectively. In concurrence with the previous studies, this study also confirms that AS is a strong denitrification basin, but BoB is not. It is mainly due to the slight difference in oxygen level between the Arabian Sea and the Bay of Bengal: BoB being slightly more oxygenated than AS. Also, we found that N* decreases exponentially in the AS when the oxygen concentration is less than 2 µmol/kg; N* is as low as ~-20 µmol/kg in the core of the AS Oxygen Minimum Zone (OMZ). Along the Oman coast, which is outside the core of OMZ, N* shows large negative values (~-10 µmol/kg).

Keywords: OMZ, dentrification

Sub-Theme-07

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Variability in phytoplankton community along the southeast coast of India during the northeast monsoon

[ABS-07-0157]

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Phytoplankton is the base of the food web, is highly sensitive to environmental changes, and quickly responds to the surrounding environment. Thus, the phytoplankton community is mainly structured by physico-chemical characteristics of the aquatic ecosystems. Freshwater runoff that results from monsoonal rainfall plays a prominent role in coastal water biogeochemistry. The present study was carried out to identify the potential changes in phytoplankton species composition with respect to environmental parameters during the northeast monsoon period along Tamil Nadu, southeast coast of India. Surface water samples were collected to analyze the physicochemical parameters and phytoplankton assemblages during the northeast monsoon period in 2020. Significant spatial variability was noticed in dissolved inorganic nutrients, suspended particulate matter, and salinity during the study period. Higher concentrations of suspended particulate matter and salinity were observed on the southern side than on the northern side of the study region. Higher nutrient concentrations, particularly dissolved inorganic nitrogen ($p<0.05$), coincided with higher phytoplankton abundance. A total of 62 phytoplankton species were identified along the coast during the study period, of which 55 species, 6 species, and 1 species belonged to diatoms, dinoflagellates, and cyanobacteria groups respectively. Though diatoms dominated phytoplankton group in the entire study region, the dominant species varied from station to station. The variations in salinity and nutrient concentrations brought significant changes in species diversity and shifts in dominant species. Pseudo-nitzschia spp. showed the highest abundance in the northern side, which had the lowest salinity and higher nutrient concentrations, and decreased towards higher salinity regions. Salinity showed negative relation ($p<0.05$) with species diversity index, and higher salinity and lower nutrient regions shared their dominance (~50%) with many species such as Navicula sp., Thalassiosira sp. Rhizosolenia sp. and Dactyliosolen sp. Our study revealed that salinity and nutrient concentrations were predominately regulating phytoplankton composition and

diversity along the coast. The shifts in diatom dominance caused by environmental gradients ultimately influence higher trophic levels and food web structure in the coastal waters.

Keywords: Dissolved inorganic nitrogen, Salinity, Indicator species, Species diversity

Long term seaweed cultivation: A positive impact on benthic ecological diversity

[ABS-07-0212]

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Seaweed cultivation is considered as an increasingly widespread and conspicuous agroecosystem in marine seascape that provides diversified ecosystem services. It is one of the fastest-growing primary production sectors globally as well as in the coastal part of India, providing food security and employment. CSIR-CSMCRI has a huge contribution in sustainable management of seaweed cultivation in the southern part of India. Seaweed as an ecosystem engineer, can increase ecosystem multifunctionality and transform bare mudflats into a highly productive ecosystem that significantly scale-up from lower to upper trophic levels. However, there are limited studies available focusing the interplay between seaweed cultivation and maintaining ecosystem health. Hence, the present study attempts to investigate the impact of long-term cultivation on the benthic biota in different coastal habitats. A rapid benthic survey was performed during the month of January to February 2023 in three different seaweed (Kappaphycus alvarezii) cultivation sites along with control sites across the coastal belt of Mandapam to Rameswaram to assess the effect of long-term seaweed cultivation in habitat modification and regulating macrobenthic population. Sampling was performed through vertical profiling upto the depth of 30 cm, separating into three different strata to assess the sedimentological parameters (particle size distribution, TOC, heavy metals and mineralogical composition) and macrobenthic assemblages. In concordance with our hypothesis, total macrobenthic assemblages showed higher abundance and biomass, compared to control sites. Additionally, the cultivation sites create preferable habitat for diversified macrobenthic groups such as polychaete, bivalve, crustacea, cnidaria. Polychaete with a total of 22 families and more than 30 genera showed the highest density compared to other groups. Polychaete abundance was significantly high in the upper strata which are characterized by high organic content that allows deposit feeders like Spionidae, Nereididae, Eunicidae to settle. Overall macrobenthic diversity was less in

the control sites, majorly dominated by the members of Capitella sp. and oligochaetes. The species composition along with particle size distribution also showed a significant variation between different cultivation sites (rocky shore and sea grass habitat) which depicts the influence of habitat heterogeneity in the composition and functionality of benthic components.

Keywords: seaweed cultivation, macrobenthos, polychaetes, habitat heterogeneity, vertical profiling

Diversity assessment of deep-sea organisms from Seamounts of Arabian Sea using environmental DNA metabarcoding

[ABS-07-0364]

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Seamounts are the elevated mountain like structures in the deep sea which accommodates a plethora of organisms. The diversity of these organisms is mostly studied based on morphological taxonomic approaches. In the current study, we employed metabarcoding of environmental DNA (eDNA) to delineate the diversity of organisms in two seamounts (SMS2 and SMS3 off Mangalore, Lat between 12˚ and 14˚N, Lon between 72˚ and 74˚E) of Arabian Sea for the first time. The summit of the selected seamounts was interacting with the oxygen minimum waters at ~350 to 500 m depth at off Mangalore. The cytochrome oxidase-I (COI) gene was amplified from the eDNA of water samples collected from the summit and periphery of the seamounts. The COI-gene amplicons were sequenced following Oxford Nanopore sequencing technology, and the sequences were analysed using QIIME-2 bioinformatic pipeline. Nearly 70 % of the sequences were not matching with COI-database (BOLD systems), indicating the existence of novel organisms in the region. The diversity indices, Pielou and Simpson evenness, show no significant variation in the diversity of organisms between samples collected from the summit and periphery of seamounts. On the other hand, there was a significant difference in the richness of organisms as indicated by Chao1 and Shannon index. Arthropods were dominant in all stations with maximum (86 %) and minimum (27 %) at the periphery of SMS2 and summit of SMS3 respectively. Protozoans were found as the second dominant phylum with their contribution topping (40 %) at the terrace of Mangalore and a lowest at the periphery of SMS2 (7 %). Other phyla detected in the study area were Annelida, Chordata, Cnidaria, Mollusca, Porifera, Nemertea, Echinodermata, Bryozoa, Onychophora, Placozoa, Chaetognatha, Brachiopoda, Ciliophora and Nematoda. The results of the study indicate the existence of diverse group of organisms in the

seamounts interacting with the oxygen minimum zones in the Arabian sea, with significant difference in the species richness between the summit and the periphery. Our results also highlight the importance of eDNA metabarcoding techniques for understanding the diversity of organisms in deep sea ecosystems.

Keywords: Seamount, deep-sea, environmental DNA, metabarcoding, diversity

Studies on metal oxide nanoparticles incorporated epoxy coatings for antifouling application

[ABS-07-0283]

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Biofouling, the unwanted attachment of micro and macro-organisms on surfaces immersed in water, poses significant challenges to the maritime industry. In recent years, epoxy nanocomposites (ENC) have emerged as a promising approach for mitigating biofouling. In this study, ENCs were developed with an individual (CuO, ZnO, TiO2) and mixed nanoparticles (NPs) each with three concentrations (0.5, 1, 1.5%). NPs incorporated epoxy coatings characterized by ATR-FTIR, TGA-DSC, contact angle, and SEM. Lab-scale bacterial and diatom adhesion assays were performed by microscopic observation using different staining techniques, biofilm-associated EPS quantification, cell counting, and surface wettability at 48, 72, and 96h. The antifouling performance of different NPs incorporated in epoxy coatings were observed in marine water for up to 100 days compared with commercial antifouling coating. A multivariate statistical analysis was performed to understand the correlation between different biofouling communities and water parameters. In the lab scale study, mixed NPs incorporated epoxy coating (1.5%) revealed minimum bacterial and diatom adhesion along with less surface wettability. In in-situ conditions, the percentage area covered by fouling organisms exhibited a maximum coverage on control surfaces and a minimum on mixed NPs incorporated epoxy coating (1.5%) with barnacles and tubeworms as a significant fouling community followed by the green mussel. These coatings have shown excellent performance in reducing the adhesion of marine organisms, including bacteria, algae, and barnacles. Furthermore, long-term stability and durability were observed in NPs incorporated with epoxy coating under harsh marine conditions, making them suitable for antifouling applications.

Keywords: Biofouling, Antifouling coatings, Epoxy nanocomposite, Nanomaterials

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A taxonomic study of microzooplankton in the coastal water of Goa during north-east monsoon period (2022-23)

[ABS-07-0154]

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Microzooplankton is a collection of heterotrophic and mixotrophic organisms with sizes ranging from 20 to 200 μm that play a major part in the marine food web. A taxonomic study of microzooplankton was carried out in coastal water of Goa. Water samples were collected from different depths (upto 47m) from 14 coastal stations. Additionally, surface water samples were obtained from eight different beaches, from Dona Paula Jetty to Anjuna Beach. Salinity and water temperature data from the coastal stations was recorded by using a CTD. The water temperature was typically between 22°C and 28°C, and the average salinity was around 34 PSU. A total of 109 microzooplankton species/taxa have been observed from the study within which six groups of organisms have been identified. These were ciliates, dinoflagellates (heterotrophic and mixotrophic), radiolarians, crustacean auplii, rotifers and foraminifera. There have been two types of ciliates observed. Loricate ciliates had the most number of species, with 54 species from 9 different families, whereas aloricate ciliates had two species from two families. In loricate ciliates, the family Codonellidae had the highest dominance, followed by Tintinnidae. Tontoniidae has the most species diversity among aloricate ciliates. The study observed that loricate ciliates outnumbered other microzooplankton groups. A total of 20 species of heterotrophic and mixotrophic dinoflagellates from four families have been identified. Ceratiaceae had the most diversity, whereas the Ceratocoryaceae had the least. 6 different species of heterotrophic dinoflagellates and 14 species of mixotrophic dinoflagellates have been observed. Loricate ciliates are more prevalent in terms of variety, whereas dinoflagellates are more common in terms of density. The study identified 22 radiolaria species from three primary groups. Radiolaria, which comprised 16 species from four Polycystina families, and Acantharia, which includes 5 species from 3 families, have both been identified. Crustacea nauplii consisted of seven taxa with different life stages. Rotifer contained only one species, and foraminifera also contained only one species during the study period. The study also describes occurrence of new records of some species to the Goa coast.

Keywords: Microzooplankton, Arabian Sea, Ciliate, Dinoflagellate, Radiolaria

A study on ecological diversity of benthic diatoms from sub-littoral sediments of south Andaman

[ABS-07-0141]

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Diatoms are a group of microscopic algae belonging to the phylum Bacillariophyta composed of a siliceous exoskeleton. They play a pivotal role in primary productivity, carbon sequestration, marine nutrient cycling and in the transformation of inorganic carbon into organic matter. The current study aimed to investigate the ecological significance of diatom distribution in relation to the physical and chemical factors such as temperature, pH, organic carbon, sediment size, dissolved oxygen and salinity prevailing in the study area. Taxonomic identification provides better knowledge of the benthic diatom diversity, distribution pattern and ecological roles. In the 6 month study period, a total of 30 genera and 18 species of benthic diatoms were identified from the sublittoral sediments (~20m depth) of the South Andaman Sea. Of the three stations studied, station 2 had the highest benthic diatom abundance (38%) compared to the other two stations. PRIMER-E Ltd. software was used to analyse and interpret the ecological data. Principal component analysis showed pH as the key factor that displayed wide variation during the study period, which strongly correlated with the distribution of benthic diatoms species. Bray-Curtis dendrogram displayed two major clusters; the maximum similarity percentage obtained was 76.77% from the samples of station 3 during January and February 2021. Diatom species identified in the present study could be associated with the existing environmental health since their distribution varies depending on regional and local factors. These findings highlight the urgent need for more studies related to the biology, ecology, and factors influencing diatom species richness and geographic distribution.

Keywords: ecology, taxonomy, benthic diatoms, physico-chemical parameters, diversity

Assessment of mangrove defoliation by Hyblea Puera (Cramer, 1777) around the Thane Creek, India using Sentinel-2 Imagery

[ABS-07-0389]

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Mangroves are halophytic trees and shrubs found in tropical and subtropical coastal regions worldwide, thriving in brackish or intertidal water. They are known for their ability to withstand harsh conditions like high salinity. Mangroves possess unique adaptations such as intricate aerial root systems and salt filtering abilities to withstand saltwater inundation, wave impact, saturated soil, frequent flooding, and even anoxic conditions. In Maharashtra, mangrove forests are primarily located near urban areas, with Mumbai and its suburbs being the focal points. The total area of mangroves of Thane creek was estimated to be 9000 ha. Avicennia marina, the dominant species within these mangrove forests, was observed to be infested. As mangroves are persistently affected by human-induced and natural stresses, the availability of reliable, accurate, and timely mangrove information becomes essential for their conservation, protection, and sustainable management. Fortunately, advancements in remote sensing, such as the availability of high-resolution satellite data with improved spatial and temporal capabilities, enable the study of mangroves in terms of their extent, changes in cover, species composition, biomass, density of canopy, defoliation etc. The current study employed Sentinel-2 data to assess the defoliation occurring in the mangroves surrounding Thane Creek, India, resulting from the presence of Hyblaea puera (H. puera), commonly known as the teak defoliator. Additionally, ground-truth observations of defoliation within the study area were recorded from 2020 to 2022. The study effectively identified unhealthy and stressed mangroves, attributed to defoliation caused by H. puera infestation, using NDVI analysis. The distribution of mangrove infestation levels within the total mangrove area was estimated as follows: 19% highly infested, 19% moderately infested, 35% low infested, 9% very low infested, and 7% remained uninfested. The infestation impacted an extensive area of over 8,370 hectares of mangroves. In the present study, the annual infestation in mangroves was investigated from Feb 2018 to Oct 2022, analyzing its causes, impacts, and its relationship with meteorological parameters like temperature, humidity, and rainfall. The study suggests further research to investigate outbreak causes, examine insect preferences for specific mangrove species, and explore additional implications of defoliation.

Keywords: Mangroves, Thane Creek, Defoliation, Infestation, Sentinel 2, NDVI

First record of epibionts on macrobenthos in mangrove habitats, India
[ABS-07-0290]

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Mangrove habitats are well-known for its thriving fishing industry (Crustaceans, mollusks, echinoderms, and other invertebrates) are likely to be found in the benthic ecology. Records of epibionts may have been ignored in prior ecological studies dealing with polychaetes, crustaceans, and mollusks, suggesting that this connection may be more prevalent than it appears. The preliminary research is based on a careful examination of the existing literature and fresh data to provide a complete picture of the current knowledge of benthic invertebrates-ciliate epibiosis interactions in Indian coastal waters. The samples were collected from 40 sites in coastal waters, mangrove creeks, Pulicat lake and Kakinda Bay, as part of the ongoing Ecosystem Service Project. During the analysis, the epibionts of Nassarius foveolatus (Dunker, 1847) (nassariidae) and Onuphis eremita (Audouin and Milne Edwards, 1833) were noticed. Over 3000 individual specimens (110 benthic species) were analyzed in by light microscopy, and through electron microscopy, among the all examined annelids, molluscs and arthropods nearly 3% of species presented epibionts bodies. This study is the first time for the Ectosymbioant investigations on benthic biota in. The association between hosts-epibionts can be considered an ectocommensalism, in which ciliates have complex trophic relationships and increased food availability. As a result, it merits cautious consideration and additional examination. The purpose of this study is to know the Ectosymbioant of annelids, molluscans, arthropods to generate more knowledge about this ecological relationship, and for better understand the status of mangrove ecosystem biodiversity their ecological functions.

Keywords: Ciliates, Protozoa, Mangrove Biodiversity, Trophic interactions, Coringa

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Metagenomic profiling of virome associated with penaeid shrimp culture system

[ABS-07-0303]

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Viruses are ubiquitous entities abundant across different aquatic systems. However, they remain vastly unexplored. A better understanding of the microbial communities associated with the culture environment used for aquaculture is a prerequisite for effective management. Early detection and characterisation of potential pathogens can be beneficial in bringing about effective prevention mechanisms. The profiling of the viromes also reveals insights into the roles played by the viruses in nutrient cycling, food web dynamics and many more. The present work has looked into the sediment virome composition of the semi-intensive shrimp culture pond. The viral particles were concentrated and purified from the sediment by centrifugation, filtration and flocculation. High throughput sequencing followed, resulting in the generation of the metavirome. The analysis of the generated sequences revealed distinct and diverse viral communities with a dominance of bacteriophages. A significant portion of the virome was composed of phages of potential aquatic pathogens, especially the Aeromonas phage, hence revealing the system's health status. However, a high abundance of these bacteriophages also points out their prominent role in controlling these bacterial pathogens. The functional characterisation was also performed, revealing the putative gene ontologies and their functions. Hence the results show that metagenomics is a valuable tool that helps explore and understand the viral community associated with aquaculture systems.

Keywords: Metagenomics, Phages, Aquaculture, Virome, Next generation sequencing

Bacterial diversity of Visakhapatnam coastal water: A short term study on pollution index

[ABS-07-0315]

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Marine pollution has become a big threat to all aquatic species and also to humans because it is unsafe for people to swim in seas near beaches and coastlines. Some of the pollutants end up in the marine environment and cause harmful effects on aquatic species and human health. Several beach resorts have come to existence as part of tourism development in the coastal areas. As a result, anthropogenic activities have been increased in the beaches affecting the flora and fauna. This study was undertaken to evaluate the effect of pollution on the beach water at 13 numbers of selected stations (VC1 to VC13) along the Visakhapatnam beach during the February 2023. The proportion of fecal coliform to fecal streptococci was used to calculate the Pollution Index (PI). The lowest value of DO (2.60 mg/l), pH (7.73) and salinity (24 PSU) while higher concentration BOD (9.80 mg/l),Total Viable Count (TVC) 6.20 ×104 CFU/ml, Total Coliforms (TC), 3.05 ×102 CFU/ml, Escherichia coli (E. coli) 0.54 ×102 CFU/ml, Fecal coliforms (FC) 0.22 ×102 CFU/ml, Shigella (SHLO) 0.76 ×102 CFU/ml, Salmonella (SALO) 0.16 ×102 CFU/ml, Klebsiella (KLO), 2.23 ×102 CFU/ml, Streptococcus faecalis (SFLO) 0.54×102 CFU/ml, Pseudomonas aeruginosa (PALO), 0.03 ×102 CFU/ml were recorded at VC1, VC2, VC8, VC9, VC11 and VC13. Salinity, BOD showed negative correlation whereas DO and pH showed the positive correlation with Total viable counts (TVC) of beach water. Very high PI was recorded in VC8, VC10, VC11 and VC13 indicating unsuitability for recreational purposes.

Keywords: Pollution index, Bacterial count, Coliforms, Streptococci, Pseudomonas, Shigella, Klebsiella

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The Southern Indian Ocean calcifying nannoplankton in the changing climate

[ABS-07-0375]

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Coccolithophores are a key component of the marine ecosystem and sequester large amounts of dissolved CO2 in the ocean interior through biological carbon and carbonate counter pumps. It is estimated that out of the global oceanic carbonate deposits, ~50% is contributed by coccolithophores alone. However, on the verge of changing climatic scenarios, coccolithophores may alter their biogeographic boundaries and functioning which may rework the biological carbon and carbonate counter pumps. We have assessed the coccolithophores biogeography and calcification in the Southern Indian Ocean during the past 10 years utilizing data collected in seven Southern Ocean/Antarctic expeditions between the area 30oS and 67oS within the austral summer period. Our study indicates that (1) the coccolithophores southward expanse is highly dynamic which shifts from 48oS during the early-austral summer (November-December) to 65oS in the mid-austral summer (January-February) and returns back to 45oS during the late austral summer, attributing to variations in nutrient concentrations, and grazing pressures; (2) coccolithophores calcite production (specifically Emiliania huxleyi) is higher in the subantarctic region owing to larger coccosphere size compared to subtropical and polar frontal regions; and (3) E. huxleyi in the polar waters are more heavily calcified by extracellular calcite precipitation, as a defense mechanism against low temperature and pH. In addition, we documented several new coccolithophore species/varieties from the Southern Indian Ocean with distinct morphologies, and probably native to the region. We presume that in the coming decades, lowering pH, increased irradiance, meltwater and stratification will affect coccolithophore abundance, standing stock, calcification, and thus carbonate drawdown. In addition, in the changing climatic scenario, coccolithophores may show more genotypic and phenotypic plasticity which will lead to the formation of new species/varieties.

Keywords: Coccolithophores, Climate Change, Southern Ocean, Ecology, Biogeography

Hydrophobic Topographies created by soft lithography for biofilm attachment studies

[ABS-07-0278]

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Biofilm formation is a common challenge faced by various industries, including those operating in marine environments. In marine environments, biofilm consists of complex communities of microorganisms, including bacteria, algae. These microorganisms attach to submerged surfaces, especially to the hulls of ships which eventually leads to corrosion and structural damage. Thus, soft lithography opens novel applications in anti-biofilm properties and self-cleaning engineered surfaces. In this study hydrophobic topographies are created using soft lithography on silicone modified polymer to evaluate its attachment studies. PDMS is a silicone based organic polymer and it is widely used in soft lithography because of its biocompatibility, low toxicity and mechanical flexibility. It has been observed that its water contact angle is in the range of 109° with a surface energy of 7.59 j/m2 after standardization with a curing temperature of 80°C. Further the polymer was characterized using FTIR and TGA to study its functional properties and its thermal stability. This study focusses on the replication of the unique hydrophobic surface of Gore-Tex fabric using Silicone modified polymer as a mimic substrate, which is further used to investigate the biofilm attachment studies on the replicated surface. The hydrophobicity of the negative replica is evaluated by measuring the contact angle of water droplets on the surface. It has been observed that the negative replica exhibits a high contact angle with 115°, indicative of good hydrophobic properties similar to Gore-Tex. To assess the biofilm attachment studies on the negative replica, the surface is exposed for adhesion studies and comparative studies are conducted between the replica surface and a control surface to assess the extent of biofilm adhesion, growth and stability. Since the negative replica exhibited high hydrophobicity, it hinders comparatively lesser biofilm formation. Understanding the surface's anti biofilm properties will contribute to the development of novel materials

and coatings with enhanced resistance to biofouling, facilitating the design of more efficient antimicrobial surfaces and the development of effective strategies for combating biofilm associated problems in marine industries.

Keywords: Biofilm, Hydrophobicity, soft lithography, Gore-Tex, Negative replica

Thermodynamic approach to quantify biofilm formation by marine benthic diatoms

[ABS-07-0276]

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Biofilm formation by marine diatoms is a complex process influenced by various factors and parameters. In this study, we investigated the biofilm formation abilities of marine diatoms on different substrates, including glass, mild steel, and polypropylene. Surface characterization data played a crucial role in understanding the biofilm formation process. Contact angle measurements provided insights into the wettability and surface hydrophobicity of the substrates, while surface energy calculations helped evaluate the interaction between the diatoms and substrates. Attenuated total reflection Fourier-transform infrared spectroscopy (ATR-FTIR) was employed to identify functional groups and chemical compositions present on the substrate surfaces. The analysis involved assessing the percentage adhesion, quantifying extracellular polymeric substances (EPS) and employing Alcian blue staining. Additionally, thermodynamic approaches were used to quantify the biofilm formation process. The experiments were conducted over a period of 24, 48, 72, and 96 hours to evaluate the temporal dynamics of biofilm development. The results demonstrated that the biofilm formation by marine diatoms varied depending on the substrate and the duration of exposure. The percentage adhesion analysis revealed differences in the diatom attachment to glass, mild steel, and polypropylene surfaces over time. EPS extraction and quantification provided information on the quantity and composition of the extracellular matrix produced by the diatoms, contributing to biofilm formation and stability. Alcian blue staining facilitated the visualization and assessment of transparent exopolymer substances (TEP). The thermodynamic approaches enabled the quantification of the biofilm formation process based on surface free energy calculations. This allowed for a deeper understanding of the thermodynamic interactions between the diatoms and substrates, shedding light on the driving forces behind biofilm formation. The comprehensive analysis of biofilm

formation by marine diatoms on different substrates and over varying time periods provides valuable insights into the complex mechanisms underlying this process. The combination of surface characterization techniques, EPS quantification, Alcian blue staining, and thermodynamic approaches enhances our understanding of the biofilm formation process and facilitates the development of strategies for managing biofouling, bioremediation, and biotechnological applications in marine environments.

Keywords: Diatoms, Biofilm, surface free energy, EPS, cell-substrate interaction

Possible environmental factors influencing jellyfish blooms in the North-eastern Arabian Sea

[ABS-07-0477]

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Jellyfish blooms are a fascinating phenomenon that has captured the attention of researchers worldwide due to their ecological and environmental implications. Numerous studies indicate the rising jellyfish population globally, which impacts adversely on various maritime activities viz., tourism, fisheries, and industrial sectors. To overcome these issues, it is paramount important to study and understand the jellyfish bloom dynamics as well as the influencing environmental factors for jellyfish bloom. In the present study, we investigated the vertical distribution of temperature, salinity, and other physical parameters in relation to jellyfish blooms. Understanding these relationships is crucial for elucidating the factors driving jellyfish bloom and population dynamics. Through a combination of onboard experimental surveys and environmental parameters analysis, this study examines the conducive environment for jellyfish blooms in off-Jakhau of North-eastern Arabian Sea. We further investigated the role of temperature and salinity gradients, as well as their interactions with other physical parameters such as light intensity, dissolved oxygen, and nutrient availability on jellyfish bloom. Results demonstrate significant correlations between jellyfish bloom and vertical variations in temperature and salinity. These findings will contribute to a better understanding of the mechanisms underlying jellyfish blooms and their ecological implications. By unraveling the relationships between temperature, salinity, and other physical parameters, this research will enhance the ability to predict and manage jellyfish blooms in marine ecosystems. It also provides valuable insights for coastal management, fisheries, and conservation efforts.

Keywords: Jellyfish bloom; Ecology; Temperature; Salinity; Arabian Sea

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Diatom spores from the Eastern Arabian Sea: Capturing the missing link using Flow Imaging Microscopy

[ABS-07-0419]

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Diatom is a major component of the phytoplankton community in the ocean. In coastal regions, diatoms comprise 40-50% of the total phytoplankton biomass and play an important role in the pelagic food web. Pelagic bloom of diatoms has a life cycle that consists of two phases: a growth phase in which they proliferate in nutrient-rich water and a sinking phase during which they deposit biogenic material on the ocean floor. As a transitional form between the pelagic and benthic realms, spore or resting stages can survive for an extended period in the dark and can resume growth when exposed to light and nutrients again. Regular monitoring of phytoplankton can reveal details about the composition, and diversity of phytoplankton communities. The classical or conventional microscopy approach for cell enumeration provides the most accurate and trustworthy results however, the manual task is tedious, time-consuming, and requires special expertise. But the development of automated flow imaging tools and computer vision technology makes monitoring plankton much easier and faster. In this study, we used a Flow Imaging Microscope (FlowCam 8400 series) to analyze the microplankton population from the coastal region of Goa, India during the early, peak and late phases of the summer monsoon. We encountered a high number of diatom spores (Chaetoceros lauderi and Cerataulina pelagica) during the peak summer monsoon (August) in the water column for the first time from the Indian waters. The presence of diatom spores in the water column was associated with the upwelling forcing and could subsequently contribute to phytoplankton bloom dynamics. The study highlighted that advanced techniques such as automated flow imaging in marine research allow analyzing of large sample volumes quickly, enabling to capture of rare events/minor species such as phytoplankton spores/cysts with ease. This would provide an early detection of the phytoplankton blooms which have become more frequent due to changing climatic conditions.

Keywords: Phytoplankton, Summer Monsoon, Chaetoceros, FlowCam, Upwelling

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Population variations and reproductive isolation of False Trevally (Lactarius lactarius) in the Eastern Arabian Sea: Insights from Geometric Morphometric Analysis

[ABS-07-0349]

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Lactarius lactarius, commonly known as false trevally, is widely distributed in Indian waters and forms an important local fishery along the west coast. However, our knowledge about the population and stock structure of this fish in Indian waters is limited. This study aims to report population variations in L. lactarius using geometric morphometric analysis of body shape. Fish were collected from four different geographical locations (Mumbai, Ratnagiri, Mangalore, and Calicut) along the west coast of India in 2019. A total of 125 fish were analyzed for shape variation using landmark-based geometric morphometric analysis (GMA). The fish collected from different locations exhibited significant variations in their phenotypic characters, primarily related to feeding and locomotion strategies. Principal component analysis distinguished the population into two major morphotypes: the northern (Mumbai and Ratnagiri) and southern (Calicut) populations. The southern populations were characterized by larger eyes, posteriorly oriented pectoral fins, larger body sizes compared to their counterparts, and more terminal mouths. Mangalore, acting as an ecotone between the northern and southern stations and fishes collected from this location showed significant overlapping in phenotypic characteristics with both populations, indicating gene flow between the northern and southern populations. The heterogeneous habitat conditions and oceanographic characteristics of the northeastern and southeastern Arabian Sea act as barriers, resulting in reproductive isolation between the populations. The observed morphological variation in L. lactarius can be attributed to variations in habitat conditions. Limited studies have been conducted on the population differentiation of commercially important fishes in Indian waters, making their management and resource assessments challenging and less reliable. Our findings will contribute to the development of appropriate policies for the management and sustainable use of this fishery resource.

Keywords: Lactarius lactarius, False travelly, population variations, geometric morphometric analysis, eastern Arabian Sea

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Assessing the disturbance and recovery trends in the Coringa mangroves: A LandTrendr analysis for 2000-2022

[ABS-07-0275]

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Coringa mangroves situated in the south of Kakinada bay are home to endangered species and migratory birds. These mangroves protect the coastline during storms and tsunamis, acting as a natural barrier. Mangroves also serve as nursery grounds for commercial fish, thus providing livelihood to the local communities. Despite their importance, mangroves are degraded rapidly due to anthropogenic activities. Thus, the present study is focused on detecting mangrove dynamics for the period 2000-2022 using the LandTrendr algorithm executed on ArcGIS Pro and Google Earth Engine. We first prepared a multidimensional raster using Landsat imagery and derived NDVI (Normalized Difference Vegetation Index), which is used to detect trends in mangrove disturbance and recovery using the LandTrendr algorithm. Results suggest that severe mangrove disturbance occurred in the years 2001 and 2004 due to the aquaculture and industrialization. Significant mangrove recovery has also been observed in degraded areas starting from the year 2002 due to the restoration strategies.

Keywords: Coringa mangroves, Coastline protection, Anthropogenic activities, Mangrove dynamics, LandTrendr algorithm, Restoration strategies, ArcGIS Pro, Google Earth Engine

Influence of tidal phases on temporal variability of the predominant picophytoplankton, Synechococcus, in a tropical monsoonal bay

[ABS-07-0160]

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Synechococcus (SYN) is a major group of the picophytoplankton community (< 3μm in size) in the coastal marine ecosystems. It contributes significantly to the coastal primary productivity and forms an integral part of the microbial food web. The coastal ecosystems are dynamic as they experience strong physical forces such as waves, tides and freshwater runoff, which controls the biogeochemistry and plankton distribution per se. For better understanding the SYN dynamics, the present study was undertaken to assess the temporal variation in the SYN cell abundance during the different tidal phases in Dona Paula Bay located on the west coast of India. The Bay is impacted by semi-diurnal tides and monsoonal freshwater runoff from the Zuari River. Bimonthly samplings were conducted from September-2022 to April-2023 during spring tide (Lowest Low Tide-LLT and Highest High Tide-HHT) and neap tide (Low Tide-LT and High Tide-HT). The surface water samples were collected for the analyses of environmental parameters (temperature, salinity, Secchi Disc (SD) depth, Suspended Particulate Matter (SPM)), and SYN cell abundance. Flow Cytometric analysis revealed highest cell abundance during February (pre-monsoon season). The highest annual temperature and lowest SPM concentration reflecting in the deeper euphotic depth probably played a significant role in the SYN proliferation. SYN were abundant mostly during neap tide due to prevalence of conducive growth conditions. However, exceptions were observed in January, wherein high SYN abundance coincided with relatively higher SD depth than the neap tide. SYN exhibited distinct intra-tidal variations that differed during the spring and neap tides. During spring tide, irrespective of sampling time, SYN abundance was higher mostly during the LLT, which could be attributed to the relatively calmer conditions. On the contrary, during neap tide (except in April) SYN abundance was higher mostly during HT coinciding

with higher SD depth and temperature. In April, the high SYN abundance coincided with seasonal temperature maxima (32oC) during the LT. Such tidal phase variations in the SYN abundance can have cascading effects on the immediate consumers thereby influencing the microbial food web and also highlights the importance of high sampling resolution to better understand the population dynamics.

Keywords: Synechococcus, cell abundance, high tide, low tide, tropical bay

Diversity and distribution of Lithodid king crabs in the Indian waters, with a note on their parasites

[ABS-07-0153]

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Crustaceans of the anomuran superfamilies Lithodoidea and the prevalence of their parasites are inadequately documented in the Indian Ocean. Published literature reported a few surveys (HMS Challenger, RIMSS Investigator, John Murray Expedition, Meiring Naude cruises, BIOSHELF, French and Australian expeditions, and FORV Sagar Sampada) in the continental shelf and slope regions. The present work summarizes data from literature and observations from the FORVSS surveys. The consolidated data revealed 24 species in three genera of the family Lithodidae. These include one new species and one first geographical record for India. Paralomis White, 1856 was the most speciose genus (14 species), followed by Neolithodes A. Milne-Edwards & Bouvier, 1894 (six) and Lithodes Latreille, 1806 (four). Among the regions, the South-western Indian Ocean was reported to have recorded ten species from three genera, followed by the Australian waters (eight species from three genera), the Northern Indian Ocean (five species from two genera), and the South-eastern Indian Ocean (one species); all regions recorded species exclusively suggesting a high degree of endemicity. Solely deep-water species (> 200 metres depth) accounted for 92% of the total diversity, whereas only 8% were reported from the shelf and deep waters. Out of the present specimens (N = 32), only 12 belonging to Paralomis indica Alcock & Anderson, 1899 harboured parasitic rhizocephalan barnacles on the underside of their pleons (abdominal region). Despite the vast geographical extent, the Indian Ocean regions, particularly the Northern and Central Indian Ocean, are scantily surveyed, necessitating extensive systematic surveys to unravel the lithodoid diversity and prevalence of parasites across this region.

Keywords: Lithodoidea, Distribution, Parasite, Indian Ocean

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Decoding the productivity, Morphological Adaptation, and C-N-S gene profiling of the Heterotrophic community in the Eastern Arabian Sea amidst the South West Monsoon

[ABS-07-0487]

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Bacteria play a significant role in the dynamics of marine ecosystems. The ratio of primary productivity to that of heterotrophic productivity varies drastically in different trophic environments. The present study focuses on primary and heterotrophic coupling in the Eastern Arabian Sea (EAS) during the end of summer monsoon (September). We hypothesize that the ratio of primary to heterotrophic productivity, bacterial biomass and community distribution varies from south to north in the EAS. Measurements were made along the EAS from 4 stations (Kochi and Mangalore (south), Goa and Mumbai (north); 9°N-21°N) during a cruise in FORV Sagar Sampada in September, 2019. The water samples were analysed for determining the total bacterial production using 3H Thymidine and primary production (PP) using 14C isotopes. Bacterial abundance was determined using epifluorescence microscopy and prokaryotic biomass was determined using Scanning Electron Microscope (SEM) as cell specific carbon density. Metagenomic analysis was carried out to understand the bacterial functional genes involved in biogeochemical (C-N-S) cycles of Kochi and Mumbai transects (coastal and offshore-200m) using Nanopore sequencing. Results showed that PP and heterotrophic productivity are not a coupled process. The PP ranged from 0.23-51.4 mg C m-3 d-1 in the south and 0.25-18.5 mg C m-3 d-1 in the north, whereas heterotrophic production ranged from 0.13- 15.02 X10-7mol3 h-TdR L-1h-1 in the south and 0.632 to 16.95 X10-7mol3 h-TdR L-1h-1 in the north. Taxonomic composition of bacterial communities was significantly different in the north and south. Morphology, average cell size, the average cell volume (ACV) of coccoid and elongated cells decreased vertically along the south EAS (0.03-0.02 μm3), whereas it increased in the north EAS (0.02-0.06 μm3). The dominant class observed to be

alphaproteobacterial in all stations except south 200m where gamma proteobacteria dominated. Our results indicate significant variations in C-N-S genes involved in the biogeochemistry of the north and south EAS.

Keywords: Productivity, Heterotrophic community, Arabian Sea, South West Monsoon, Metagenomic analysis.

Determination of microplastics in the gastrointestinal tracts of commercially important Pelagic fishes (Carangidae) from the Chennai coast, Tamil Nadu, India.

[ABS-07-0021]

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Excessive use and improper disposal of plastics into the ocean is causing a perplexing increase in marine plastic pollution. The formation of micro plastics (>5mm in size) contributes to plastic pollution in the ocean, caused by mechanical, thermal, and biological degradation processes. These plastics are accidentally ingested by marine organisms, either directly or through the food chain. Five commercially significant pelagic fishes of carangids were found to consume micro plastic, as documented by this study. Scads such as Decapterus russelli, Megalopsis cordyla, selar crumenopthalmus, Selaroides leptolepis, and Alepes klenii, collected from the Kasimedu Fish landing center. To detect micro plastics in the gastrointestinal tracts of 500 fish (100 per species), an alkaline KOH digestion was performed. In every species tested there were traces of micro plastic found resulting in a total number of 1353 recoveries and an average abundance level is 2.7 (±) 0.06 particles/individual. Five types of micro plastics were found: fibers, films, fragments, pellets and foam, which accounted for 68.9%, 15.05%, 8.01%, 4.83%, 3.21%. Among the micro plastics red fibres were more dominant (40.3%) and the highest occurrences of micro plastics were found in the Megalopsis cordyla accounting for nearly 403 micro plastics in the species. Fourier Transform Infrared Radiation analysis (FTIR) determined that fishes ingested polypropylene (20%), polystyrene (32%), and polyamides (nylon) (48%) polymers. The diet composition of this carnivorous fish was found to be Coilia, Sardinella, Nemipterus, Thryssa, and trichurus. This study thus concludes that microplastic ingestion is in direct proportion with the diverse diet specification of the carnivorous fishes.

Keywords: Micro plastics, pelagic fishes, Gastro-intestinal tract, polymers.

Isolation and screening of seaweed-associated bacteria for their commercially important enzymes production

[ABS-07-0069]

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The ocean is home to a diverse range of marine organisms with varying adaptations and physiologies. Seaweeds are non-flowering photosynthetic macroalgae found from the intertidal to the subtidal zones that contribute significantly to oceanic biomass. The surfaces of the seaweeds are covered by an organic layer, therefore allowing them to retain a diversity of associated microbial communities. Bacteria are the most widely used commercial enzyme sources. In this study, 65 epiphytic bacterial isolates were isolated from 13 different species of seaweeds collected from the intertidal regions of the Goa-West coast of India. All these isolates were screened for the five different enzymatic activities. The protein content as well as the total carbon-nitrogen content of each species of the seaweed were determined. Sixteen bacterial isolates associated with Ulva lactuca, Ulva intestinalis, Padina tetrastromatica, Sargassum sp. Scinaia sp., Sphacelaria sp., Amphiroa sp., Acrosiphonia orientalis, Gracilaria sp., Gracilaria foliifera showed the presence of amylase activity. Two bacterial isolates associated with Sargassum sp and Gracilaria sp. showed xylanase activity. Nine bacterial isolates associated with Ulva lactuca, Padina tetrastromatica and Gracilaria species showed the presence of agarase activity. Six bacterial isolates associated with Ulva intestinalis, Padina tetrastromatica, Sargassum sp., Scinaia sp., Acrosiphonia orientalis, Gracilaria foliifera showed the presence of protease activity. None of them exhibited cellulase activity. Protein concentrations were highest in Padina tetrastromatica and Acrosiphonia orientalis, with 305.8 and 372.8 µg/ml, respectively. The C: N ratio ranged from 6.1 to 17.8 (11.1±3.2%) having high values in Sargassum sp. followed by Amphiroa sp. The carbon content of the seaweed samples ranged between 16.5-39.9 (31.8 ±6.6%) having high content among Gracillaria and Dictyopteris species (39.8 %). Gracilaria and Dictyopteris are identified as promising species for carbon sequestration based on carbon content, but more research is needed.

Keywords: Seaweeds, associated bacteria, enzymes, protein, carbon-nitrogen content

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Artificial Intelligence: an emerging tool for future of deciphering the environmental complexity in World ocean resources

[ABS-07-0071]

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The coastal ecosystem is characterized by its intricate and ever-changing nature, which is attributed to the presence of a diverse array of organisms and the interplay of various physicochemical factors. In addition to their ecological significance, ocean ecosystems are known to exert a significant influence on the global climate change phenomenon. An effective prediction required huge number datasets. Hence, the examination of coastal ecosystems is imperative to discern environmental dynamics. Machine learning techniques are increasingly replacing empirical methods due to their ability to handle a large number of parameters for modelling. This makes optimization easier and results in more accurate and comprehensible predictions. Machine learning models are utilized for the purpose of predicting parameters and conducting time series analysis. To date, various machine learning techniques have been employed. Several techniques utilized in this context include artificial neural networks, deep learning neural networks, the K-means clustering method, and support vector machines (SVM). The Multilayer Perceptron (MLP) is classified as an Artificial Neural Network (ANN) and functions under the guidance of a predetermined set of inputs and outputs. The architecture of the system is composed of interconnected neurons, which are also referred to as units or nodes. These neurons operate in parallel across three distinct layers to efficiently process information. The number of neurons in the input layer is directly proportional to the number of independent variables or descriptors used to predict the dependent variables in the output layer. The MLP (Multilayer Perceptron) architecture is comprised of three distinct layers, specifically denoted as the "Input", "Hidden", and "Output" layers. Following the works of Lek et al. (2007) and Oh et al., numerous endeavours have been undertaken to construct a

conceptual model utilizing artificial neural networks (ANN). Panja and colleagues (2023) have endeavored to model the complexity of the coastal ecosystem through the utilization of an artificial neural network (ANN) model. Artificial intelligence (AI) has the potential to serve as a highly effective instrument in constructing more precise predictive models for the future and comprehending the intricate dynamics of ecosystems.

Keywords: Coastal Ecosystem, Machine learning, Artificial Neural Network, Multi layer perceptron, Ecological complexity

Insights into bacterial community structure, their metabolic profiles, and resilience in the sedimentary environments of Kongsfjorden: A case study from the Arctic

[ABS-07-0496]

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The Arctic ecosystems are critical and climatologically sensitive, warming at three times the global average. In light of such warming signatures in the Arctic, it would be imperative to understand the effect of climatic perturbations on the microbial community structure and functions, since they form ideal sentinels of climate change. Hence, a combination of cultivation-dependent and cultivation-independent techniques along with metabolic profiling was used to reveal the bacterial diversity and their metabolic potentials associated with a west Spitsbergen fjord in the Arctic, Kongsfjorden. This fjord system functions as a local indicator for climate change in the Arctic due to the advection of warm Atlantic waters into the fjord affecting its seasonal hydrography as well as its biological communities. Our study revealed the presence of heterotrophic marine bacterial taxa belonging to Proteobacteria (?-proteobacteria), Epsilonbacteraeota, and Bacteroidetes in the fjord sediments having a strong association with environmental parameters like total organic carbon and trace metal concentration. Further, the preferential utilization of carbohydrates and complex polymeric substrates by fjord bacteria indicated their potential role in complex organic matter degradation in the fjord. An increase in the concentration of Hg, Pb, Cd, and Cu from inner to outer fjord sediments in the study suggested the long-range transport of pollutants into the system via the West Spitsbergen current. The study also revealed the presence of bacterial species closely related to Psychrobacter glaciei, (99.72%), Halomonas neptunia (99.57%), and Planococcus halocryophilus (100%) which could effectively bioaccumulate metals such as Hg, Pb, Cd, Ni, Co, Zn, and Mn. The whole genome analysis of these resilient species revealed well-developed metal-resistant operons (mer, czc, ars), and antibiotic/multi-drug-resistant genes in their genomes, substantiating their role for bioremediation applications in

Polar Regions, which is a potentially transformative solution for ecosystem restoration.

Keywords: Fjord, bacterial diversity, trace metals, pollutants, bioaccumulate, bioremediation

Impact of shallow water hydrothermal vent water on the associated microbiota of Scleractinia Tubastraea aurea; an in-situ transplantation study.

[ABS-07-0092]

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The extreme environment of shallow water hydrothermal vents off Kueishan Island is a natural laboratory to understand the effect of acidification and other global change factors. The azooxanthellate Scleractinia Tubastraea aurea is found abundant in this unique extreme environment. In the present study, we tried to analyze the influence of shallow water hydrothermal vent waters off Kueishan island in structuring the bacterial communities associated with the coral. After cross-transplanting the coral from HV to Fulong and Fulong to HV, we analyzed the changes in bacterial community structure. Using 16SrRNA gene primers, we amplified the V1-V9 full-length (~1.5 kbp) 16S rRNA gene, following the SQK-LSK109 protocol (Oxford Nanopore Technologies, Oxford, UK) we performed nanopore sequencing libraries. No significant difference in alpha diversity indices was observed between coral samples after transplantation. Sulfurovum and Endozoicomonas were dominant in the coral samples collected from the HV site, while Rugeria was abundant in the coral samples from the Fulong site. However, on cross-transplantation, we observed a constant decrease in the abundance of Sulfurovum and an increase in Endozoicomonas abundance in the corals transplanted to Fulong from the HV site, while we observed an increase in Sulfurovum abundance in coral samples moved to the HV site from Fulong. Our current results clearly demonstrate the influence of vent water on the bacterial community composition of T. aurea. However, our further analysis will help to fully understand the impact of vent water chemistry and the role of dominant bacterial groups in host resilience.

Keywords: Tubastraea aurea,microbiome,resilience,shallow water hydrothermal vent

Diversity, distribution and population ecology of intertidal Asteroidea from the rocky shores of Gujarat, India

[ABS-07-0016]

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Present study was aimed to evaluate the basic ecological status of intertidal Asteroidea from the rocky shores of Gujarat. In this study, eight rocky shores viz., Okha, Shivrajpur, Dwarka, Mangrol, Veraval, Dhamlej, Simbor and Diu of the Gujarat coastline were selected and surveyed extensively from January to December 2021. Though the shores studied are situated along a continuous coastline, significant spatiotemporal variations in the diversity, distribution and density of the intertidal Asteroidea were observed. Four intertidal Asteroidea Echinaster purpureus, Anthenea rudis, Aqulionastra lorioli and Aqulionastra burtoni were identified and studied further. A total 12 color morph of the A. lorioli was reported from all the studied areas. Present study revealed that the species diversity and density of Asteroidea were varied over annual and diverse spatial scales. Diversity indices suggested lower community stability and species richness with moderate species evenness at all the studied sites. All four Asteroidea species were found to be vertically distributed in the middle and lower intertidal zones of the selected coastline. Index of dispersion suggested a general uniform and random distribution pattern. Trends in the vertical distribution pattern of Asteroidea were more constant and clearer, even though they have showed variations in individual Asteroidea species, while, in terms of general distribution pattern, showed spatial variations. We have noted that at Gujarat coast, Asteroidea mostly preferred microhabitats like the space underneath of rock, rock pool, shallow pool, flat rock cave/crevices and pool/puddles. It is possible that along with prevailed climatic conditions of the study period and the intertidal faunal composition therein, coastal structure and various microhabitats might have played a vital role for the observed differences. Empirical data provided in this study offers better understanding of intertidal Asteroidea and provides the baseline for future field and experimental studies on the predation, interspecific and intraspecific competition and coexistence in intertidal communities.

Keywords: Asteroidea, intertidal, rocky coast, spatiotemporal, Gujarat

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Phytoplankton distribution in the least explored regions of the Indian Ocean during spring inter-monsoon 2021

[ABS-07-0139]

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The present study addresses the distribution of microscopically analyzed phytoplankton species from the different regions of the Indian Ocean based on the samples collected from the euphotic depth during 90 days (March to May 2021) voyage onboard R.V. Sindhu Sadhana. A total of 23 stations were sampled of which four, five, and fourteen stations correspond to the northeastern Indian Ocean (NEIO, North of 5°N along 87°E), equatorial Indian Ocean (EIO, 5°N- 5°S), south-tropical Indian Ocean (STIO, 5°S -30°S), regions, respectively. The results revealed that the maximum abundance was observed in EIO followed by NEIO, and STIO. Diatoms (NEIO- 59%, EIO-50%, and STIO-48%) followed by dinoflagellates (NEIO-22%, EIO-22%, and STIO-42%) and others i.e., silicoflagellates and cyanophytes (NEIO-19%, EIO-28% and STIO-10%) were the dominant groups. Altogether 169 phytoplankton species were recorded and interestingly the dinoflagellates (90 species including 32 potentially harmful species) contribution was the maximum compared to diatoms (45 centric; 25 pennates). Both diatoms and dinoflagellates exhibited distinct north-south gradients for both cell abundance and species occurrences. In the case of diatoms, cell densities, and species occurrences were relatively more in NEIO and EIO compared to STIO, while for dinoflagellates it was the reverse i.e., more in STIO compared to EIO and SEIO. Further, among dinoflagellates, trophic-level demarcation in zonal distribution was observed i.e. dominance of mixotrophs and autotrophs in the northern region (NEIO and EIO) and STIO respectively. This presentation, for the first time, provides an overview of the spatial distribution of the phytoplankton species in the least explored Indian Ocean regions.

Keywords: phytoplankton, diatoms, dinoflagellates, northeastern Indian Ocean, equatorial Indian Ocean, south tropical Indian Ocean

Copepods and Diatoms: Classic examples of Epibiosis along the Southeastern Arabian Sea

[ABS-07-0072]

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Copepods and diatom, two ecologically significant groups of marine ecosystems, have been in epibiotic association since 1892. The hard exoskeleton of copepods provides a suitable substrate for the attachment of diatoms, although most of them are free living. The present study attempts to evaluate the copepod-diatom association and identify the epibiotic diatom and its variety of copepod hosts along the southeastern Arabian Sea. Zooplankton sampling for the analysis of epibiotic association was carried-out onboard FORV Sagar Sampada at nine transects, viz, off Kochi, off Valappad, off Ponnani, off Kannur, off Kasargod, off Mangalore, off Bhatkal, off Karwar and Goa with 27 stations. Two diatom genera, Pseudohimantidium and Protoraphis, were observed in association with various copepod hosts along the entire study area. They were ubiquitous and observed in both coastal and offshore waters. Pseudohimantidium pacificum was observed epibiotic on cyclopoid copepods, Ditrichocorycaeus affinis (54 female copepods, five male copepods and one copepod (sex undetermined)), Corycaeus sp., (3 females and 94 copepods (sex undetermined)) along the southeastern Arabian Sea. Farranula sp. as host of P. pacificum included one female (off Valappad) and one copepod, each from off Kannur and Mangalore. Along with these, four juvenile copepods also hosted P. pacificum along off Bhatkal. On the other hand, Protoraphis sp. was observed epibiotic on various calanoid copepods, Pontellina plumata (8 females, 5 males and 15 copepods (sex undetermined)), Candacia truncata (2 females), Labidocera sp. (4 females, 6 males and 2 copepods), L. minuta (21 females, 8 males and two copepod), Scolecithrix sp. (one female), Candacia sp. (one female), C. catula (3 females), Calanopia sp. (one female), C. minor (2 females and 12 copepod) and Pontella fera (2 females) along the southeastern Arabian Sea. Both diatoms mainly attached themselves to the urosome, dorsal body surface, and anterior and posterior appendages of the copepod host. These associations benefit the diatoms, although they harm the copepod hosts. The

study suggests extensive research on epibiosis in the planktonic group to understand their role in zooplankton population dynamics and structuring of the marine environment.

Keywords: Pseudohimantidium, Protoraphis, epibioticdiatoms, copepods , southeastern Arabian Sea

Autonomous Reef Monitoring Structures (ARMS): First initiative in Indian waters to capture the cryptic marine biodiversity of Andaman coral reefs

[ABS-07-0470]

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Coral reefs are exceptionally rich marine ecosystems, accruing a disproportionately high biodiversity, especially in the tropical realm. However, these fragile ecosystems are experiencing severe impacts from climate change resulting in biodiversity loss. Despite being one of the globally significant reef systems in the Indian Ocean, there is scant knowledge of coral-associated biodiversity in the Andaman and Nicobar Islands of India. Our research aims to address this gap by employing Autonomous Reef Monitoring Structures (ARMS), a standardized methodology to understand the cryptic diversity of coral reefs in the Andaman Islands. The design of these unique structures mimics a reef matrix that shelters sessile as well as motile fauna, and is thus effective at capturing the overall composition of natural communities. The present study is the first deployment of the global ARMS protocol in the coralline ecosystems of Indian waters. Altogether, twelve ARMS units were deployed at two distinct reef habitats each along the east and west coasts of the Andaman Islands at Wandoor and Swarajdweep respectively, and retrieved after around 24 months. The preliminary analysis of the ARMS units is presented here. All plates were photographed and the sessile fauna were visually identified. The sessile community on the ARMS plates were mostly colonized by molluscs, polychaete tubes, algae, bryozoans, ascidians and sponges. An analysis of the sessile fraction occupying different ARMS ¿microhabitats¿ revealed colonization preferences of the observed taxa for surface orientation, irrespective of location. The retrievals yielded a variety of motile taxa belonging to six major phyla. Phylum Arthropoda dominated the motile community, followed by Mollusca, Annelida, Echinodermata, Chordata and Platyhelminthes. DNA barcoding and metabarcoding analyses are underway to enrich the public database

with genetic information of the sessile and motile community using the COI marker. The research aims to create a comprehensive baseline data for the cryptic fauna of the Andaman reefs that will be imperative for comparative censuses at the global scale.

Keywords: Autonomous Reef Monitoring Structures (ARMS), cryptic diversity, Andaman coral reefs

Systematic review of coral-associated bacteria: Story of two Indian Ocean Seas

[ABS-07-0424]

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Marine microbes play an important role in nutrient cycling, survival, and defense against pathogens in corals. A stress event (habitat destruction, anthropogenic pollution, climate change), may alter the sensitive the coral microbiome, leading to a rise of opportunistic and potential pathogens. Although the past two decades witnessed a significant rise coral research in India, there is a noteworthy lack of coral-associated bacterial studies, attributed to the restriction of sample collection, requirement of expensive Scuba diving, and skilled fieldwork. Therefore, the aim of our study is to provide first comprehensive review of the coral-associated bacteria from major reefs of India. A total of 40 papers were considered for our study, and metadata including the reef name, geographical location, the health of coral, source of bacteria, sequencing method, was extracted. We used the data to understand the diversity and spatio-temporal distribution of bacteria associated with coral species from the reefs of India. Our study revealed that the reefs in Andaman and Nicobar have been researched the most among other five coral reefs (i.e., Gulf of Mannar, Palk Bay, Goa & Malvan, Lakshadweep and Gulf of Kutch) and three major hard coral genera viz., Acropora sp., Favites sp., and Porites sp. as the most studied genera. Palk Bay harboured 40 % of all the bacteria isolated from Indian reefs and Andaman reefs had the highest diversity of bacteria isolated from healthy corals (24%). Out of 12 coral genera, Acropora sp. (26%), Favites sp. (17%), Porites sp. (16%) have been most widely studied across the major coral reefs of India followed by Fungia sp. (14%), Montipora sp. (7%). Genera Bacillus, Staphylococcus, and Vibrio were most dominantly associated with Acropora sp., Porites sp., Montipora sp., Fungia sp., Pocillopora sp., Favites sp., and Turbinaria sp. Presence of opportunistic pathogens like common marine pathogen Vibrio (anthropogenic pollution indicator), and Bacillus (present in bleached diseased corals) indicate a deteriorating coral health. The study revealed an

urgent need to scale up the research to understand the role of microbes in coral's survival and disease prevalence.

Keywords: Coral reefs; Indian Ocean; microbes; anthropogenic pollution; climate change

Comparative evaluation of chlorination induced damage and recovery in marine phytoplankton

[ABS-07-0314]

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Coastal power stations abstract seawater for condenser cooling purposes, wherein phytoplankton species are entrained briefly (20 min) and subjected to different stress factors like biocides (chlorination), elevated temperatures and hydrodynamic forces. Under tropical conditions, maximum biocidal discharge limits are set at 0.2 ± 0.1 mg/l total residual oxidant (TRO). In the present study, the impact of power plant chlorination at 0.2, 0.5, and 1 mg/l TRO for varied exposure periods of 3, 10, and 20 min was determined using different classes of phytoplankton viz: Chlorophyceae (Chlorella sp.,); Bacillariophyceae (Centric diatom ¿ Chaetoceros sp., Skeletonema sp., Pennate diatom- Amphora sp.) and Haptophyceae (Isochrysis galbana). Cell viability in control and treated population was measured using the SYTOX® green staining and correlated with other parameters like chlorophyll a levels and total cell count. In addition, total reactive oxygen species (ROS) generation was measured in controls and treatments. Results of 20 min acute exposures at the in-plant use concentrations of 0.2 mg/l TRO revealed highest susceptibility by Isochrysis galbana>Cheatoceros lorenzianus >Amphora coffeaeformis >Skeletonema sp., > Chlorella sp. The highest tested concentration of 1.0 mg/l TRO also revealed highest susceptibility by Isochrysis galbana>Amphora sp., >Skeletonema sp., >Chaetoceros sp., >Chlorella sp. A significant increase in total ROS was observed in all concentrations and among all the phytoplankton cultures. Results reveal that the haptophycean member I. galbana, to be the highly susceptible organisms to all three tested concentration of chlorine. The Bacillariophycean members have exhibited reduced susceptibility compared to haptophycean members. Among the Bacillariophycean members viz: Pennate diatoms were found to be more susceptible than centric diatoms to all the tested chlorine concentrations. Comparatively the Chlorophycean member was highly tolerant to all the tested chlorine concentrations. Based on the data, the different

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classes of phytoplankton can be clearly demarcated as highly susceptible, susceptible and tolerant. The data provided an insight on the phytoplankton classes which will dominate in the near vicinity of chlorinate environments in the marine outfalls.

Keywords: Continuous chlorination, phytoplankton, Haptophyceae, Chlorophyceae, Bacillariophyceae.

Distribution of modern dinoflagellate cysts in surface sediment from central and south-eastern Arabian Sea
[ABS-07-0135]

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Cysts of dinoflagellates (dominant phytoplankton group) received attention as several of their species cause harmful algal blooms (HABs), produce toxins, and also act as environmental proxies worldwide. Cysts are produced as part of their life cycle or to survive adverse environmental conditions that settle in the sediment over time and might remain viable for centuries. In the Arabian Sea (AS), studies on dinoflagellate cysts are limited to the coastal waters of AS, but no information from the deeper depths. In this study, the distribution and abundance of dinoflagellate cysts in recent sediments from the deeper depths of central (oxygen minimum zone-OMZ) and south-eastern (oligotrophic) AS were investigated and compared with the previous studies from the adjacent regions. The surface sediment samples (0-2cm) were collected at 4 stations each from oligotrophic and OMZ regions at depths ranging from 100-4000m. The cysts¿ prevalence at deeper depths (3000 - 4000m) in relatively good numbers is the first report. Overall 35 cyst species were identified, belonging to 14 genera, of which 21 were autotrophic and 14 heterotrophic. In the oligotrophic (85%) and OMZ (61%) regions, autotrophic species dominated the cyst assemblage. Cysts for Spiniferites spp., and Lingulodinium sp., were the common occurrence. While, in OMZ more species like Spiniferites delicates, Spiniferites elongates, Nematosphaeropsis sp., Impagidinium sp., and Impagidinium paradoxum were recorded. The number of cyst species, abundance, diversity, and evenness were higher in the OMZ than in the Oligotrophic region. Interestingly, maximum (3505m depth in OMZ) and minimal (depth 4368m depth in oligotrophic) cysts abundance were recorded at the deeper depths. The comparison of cyst assemblage data revealed that the abundance and numbers of species (including HAB species) recorded in this study were low compared to the eastern and western AS. Further, the autotrophic cyst's dominance at deeper depths is in contrast with the heterotrophic cysts¿ dominance at shallow depths in coastal AS.

Keywords: Dinoflagellate cysts, surface sediment, central and south-eastern Arabian Sea, OMZ, oligotrophic region

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Response of phytoplankton communities to environmental changes at the oceanic subsurface chlorophyll maxima in the Northern Indian Ocean
[ABS-07-0068]

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Oceanic subsurface Chlorophyll Maxima (SCM) contributes a significant proportion to ocean primary production. Studies in Northern Indian Ocean (NIO) have reported spatial and temporal change in phytoplankton communities. However, most of them were based on surface/column integrated measurements of chlorophyll and phytoplankton abundance. Here we studied SCM associated phytoplankton communities in four unique environmental setups across NIO, through in-situ hydrographic measurements and laboratory analysis of bio-chemical variables. Western coast of India experiences coastal upwelling in the summer monsoon during which shallow SCM (< 30 m), dominated by mixed phytoplankton communities was observed. Southern Arabian Sea, which experiences high sea surface temperature (SST ~ 28-30ºC) and photosynthetically active radiation (PAR >50 Em2d-1), recorded deep SCM (~75 m) with low cell abundance, dominated by large centric and pennate diatoms (Pleurosigma sp., Coscinodiscus sp., Planktoniella sp., Chaetoceros sp., Nitzschia sp.) and prasinophytes. SCM in Southern Bay of Bengal recorded high temperature and low nutrient concentration, dominated by picophytoplankton and dinoflagellates (Gyrodinium sp., Protoperidinium sp., Oxytoxum sp. and Scripsiella sp.). In the Andaman Sea, cell abundance at the SCM was the highest of all the regions dominated by diatoms and dinoflagellates; prasinophytes; prymnesiophytes and chrysophytes. Upwelling in the western coast; cold core eddies and internal waves in the Andaman Sea, enhanced vertical mixing of nutrients, resulting in shallow SCM dominated by micro-phytoplankton; high SST induced stratification in Southern Arabian Sea pushed the SCM deeper; while warm core eddies in Southern Bay of Bengal may have led to oligotrophic conditions, supporting picophytoplankton and dinoflagellates at the SCM. Our results highlight that SCM and the associated phytoplankton communities are highly sensitive to the changing environmental

conditions. These changes lead to distinct phytoplankton communities at the SCM, which should be taken into account during satellite-based estimation of primary production and downward carbon export measurements.

Keywords: subsurface chlorophyll maxima, phytoplankton, pigment

Daylight driven vertical distribution of mesozooplankton in the Northern Indian Seas

[ABS-07-0159]

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Diurnal vertical migration of mesozooplankton in the Deep Scattering Layer (DSL) of the Indian seas is poorly sampled and studied. This cyclical vertical migration observed in the shallow seas substantially controls the fish stock accessibility. The present research is a comprehensive examination to analyze the vertical migration pattern of the zooplankton community in the Arabian Sea (AS) and the Bay of Bengal (BoB). Echo sounder profiling was conducted at shallow depths (~10-400m) of the AS (January, 2023) and BoB (March, 2023) within a period of 24 hours to monitor the diurnal vertical migration pattern of the DSL. The velocity profiles are coherent with the day (descend) and night (ascend) cycle of the DSL. Vertical migration in both basins showcased notable influence of the temporal and spatial contrast in the occurrence of day break. Delayed descent was observed in the AS contrary to BoB, owing to the impeded day break in the AS relative to BoB. The preliminary analysis is indicative of the diversified community structure of the zooplankton community at each sampling location resulting from the vertical migration. Furthermore, it is conclusive that the time of vertical migration of the zooplankton community in both the basins are distinct such that it can only be affirmed based on the day break rather than solely based on a particular time, and thus a single sampling is inadequate enough to get the complete information about the community structure of zooplankton in the water column of the AS and BOB.

Keywords: Mesozooplankton, Diurnal vertical migration, Deep Scattering Layer, Echosounder, Day break

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Spatial distribution of pathogenic bacteria in coastal waters and sediments along the Indian Coast

[ABS-07-0288]

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Globally, anthropogenic activities along the coastal waters enrich pathogenic bacterial abundance and pose a significant threat to the coastal communities. Reports on high loads of pathogenic bacteria at some locations along the Indian coast suggest the need for efficient monitoring. In the present study, we carried out extensive sampling at 8 locations Kolkata, Paradip and Visakhapatnam in the east coast; Mangalore, Panjim, Mumbai and Porbander in the west coast and Lakshadweep islands to map the spatial abundance and distribution of some of the pathogenic bacteria during Feb-March 2023. The results show that the abundance of pathogenic bacteria Vibrio cholerae, Salmonella sp., Shigella sp. and Pseudomonas aeruginosa (like organisms) in the surface water is comparatively higher in the west coast locations than on the east coast. Within the pathogenic forms analyzed, Vibrio cholerae is more abundant than the other pathogenic forms in all the locations in the surface waters, whereas Salmonella sp., is higher in the sediments. The higher abundance of the pathogenic forms of bacteria in near shore than the off-shore sampling stations in Mumbai, Panjim, Mangalore and Paradip might be attributed to the untreated municipal sewage, discharges from ships, and disposal from fishing harbours. Overall, our findings emphasize the need for improved monitoring and management of coastal waters to mitigate the risks posed by pathogenic bacteria, particularly in areas where anthropogenic activities contribute significantly to their abundance

Keywords: Pathogenic Bacteria, Coastal water, Sediment, Coast of India,Vibrio cholerae

Microcystis bloom dynamics and associated bacterial diversity from aquatic ecosystems of south India.

[ABS-07-0073]

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The intensification and expansion of harmful cyanobacterial blooms have become an increasing global concern. The possible severe ecological consequences of these blooms on aquatic, terrestrial and human health necessitate routine monitoring and understanding of the bloom dynamics of toxic cyanobacterial species. Apart from the increase in cultural eutrophication, variations in global climatic conditions and hydrographic parameters, the interaction between cyanobacteria and the associated bacteria also contributes to bloom formation. Microcystis sp. is a frequently occurring potentially toxic bloom-forming cyanobacteria with a ubiquitous distribution and is of major concern, deteriorating the water quality and possessing adverse health effects. Their mucilaginous colonies contribute a favourable niche for various heterotrophic bacteria, which can either have a positive or negative interaction with Microcystis. Most of these bacterial communities are unculturable, which restricts the complete understanding of their interactions and contribution to bloom formation. The present study has been carried out to understand the bloom dynamics of Microcystis species and molecular identification of their colony-associated culturable heterotrophic bacteria from two aquatic ecosystems in south India, with a continuous bloom of Microcystis. The study areas were regularly monitored from October 2021 to June 2022 every month. Warmer surface water temperatures of stagnant water and enriched nutrient levels significantly contributed to Microcystis bloom formation. The peak values of temperature, nitrate and phosphate at station 1 reached up to 30.5°C, 4.48 mg L-1, 1.64 mg L-1 and at station 2, 31°C, 3.45 mg L-1, and 0.62 mg L-1 respectively. During the study, twenty-eight bacteria were isolated from different groups, including Alphaproteobacteria, Betaproteobacteria, Gammaproteobacteria, Actinobacteria and Firmicutes. Firmicutes were the dominant group among all the 28 isolates obtained with the Microcystis bloom from both the study areas.

Keywords: Microcystis, Molecular identification, Mucilaginous colony, Culturable bacteria, south India.

Continuous chlorination on the physiological and cellular response in adult green mussel Perna viridis: A multimarker assessment

[ABS-07-0293]

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The green mussel Perna viridis is a major macrofoulant in the cooling water systems [CWS] of Madras Atomic Power Station [MAPS]. Continuous low dose (exomotive) chlorination (0.2 mg/l) is practiced at the station, drives out the veliger larvae from settling in the CWS, however this regime has been found to be ineffective to avoid settlement of mussels. Various size ranges of mussels (10 ¿ 110 mm) have been recorded, indicating their ability to survive, settle, tolerate and grow inside the CWS. In this study, the effect of continuous chlorination (0.2, 0.5 and 1.0 mg/L, TRO) on adult green mussels was studied by determining mortality and various stress biomarkers (physiological, genetic, metabolic and neuronal processes). Tested concentrations revealed 100% mortality after 16, 8 and 6 days for exposure at 0.2, 0.5 and 1.0 mg/l, respectively. Chlorination resulted in valve closure of the green mussel, resulting in impairing the respiratory and feeding behaviour. Extended valve closure resulted in stress and deterioration of mussel health. The excretion of pseudo faeces reduced to 68% (0.2 ppm); 10% (0.5 ppm) and 89% (1.0 ppm) compared to controls attributing to low filtering capacity due to valve closure. The genotoxicity effects of chlorine expressed as increase in % tail DNA fraction in treatments varied from 76 to 86% compared to control. Reactive oxygen species [ROS] generation was observed in all the tissues (gills, mantle, digestive gland and foot). ROS activity peaked within the first 3 days of continuous chlorination. Increased ROS was observed in gills viz: 38% (0.2 ppm); 97% (0.5 ppm); 98% (1.0 ppm) compared to controls. Subsequently, their activity decreased as a result of generation of quenching antioxidant enzymes. Production of antioxidant enzymes like Superoxide dismutase [SOD] and Catalase [CAT] was also recorded. Chlorine was found to act on nerve synapse and inhibit acetylcholinesterase [AChE] activity. AChE activity reduced in treatments viz: 84% (0.2 ppm); 72% (0.5 ppm);

80.4% (1.0 ppm) compared to controls. Chlorine was found to act on all tissues and resulted in generation of ROS as well as neuronal toxicity, which resulted in weakening of physiological and metabolic functions resulting in mortality

Keywords: Continuous chlorination, Perna viridis, Reactive oxygen species, Genotoxicity

The distribution of microphytobenthos in the central Vembanad Lake ecosystem

[ABS-07-0122]

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A study on the distribution, abundance, biomass as chlorophyll a, and community structure of microphytobenthos (MPB) was carried at 69 selected stations in Central Vembanad Lake (CVL) during the pre-monsoon and monsoon season. Both qualitative and quantitative distributions of flora along the 5 cm3 of the sediment were investigated. Numerical abundance of MPB in the sediments of CVL varied from 32 cells/cm3 (range 13-50 cells/ cm3) during monsoon to 56 cells/cm3 (range 14-77 cells/cm3) during Pre-monsoon season. The distribution of chlorophyll a observed significant seasonal variation (ANOVA $p<0.05$). The low chlorophyll a concentration in monsoon season stipulates less biomass. During monsoon, MPB was represented by 31 diatom cells (97.1%), 0.8 cyanobacteria cells (2.5%) and 0.08 silicoflagellate cells (0.4%) per cm3 sediment whereas during the pre-monsoon numerical abundance of diatoms was 56 cells/cm3 (99%) and that of cyanophytes was 0.6 cells/cm3 (1%). Silico-flagellates were totally absent during pre-monsoon. The average MPB abundance for the 69 stations in the present report are much less than the reports of earlier workers which can be attributed to higher depth range (1m to 9.5m) of the stations covered during the study.

Keywords: Microphytobenthos, Diatoms, Central Vembanad Lake, Pre-monsoon, Monsoon

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Spatial assessment of vulnerability on Molluscan Bed in Central Vembanad Lake: Special emphasis on sediment transport

[ABS-07-0199]

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Kerala experienced a disaster of the worst flash flood in its history with the flood of August 2018 and the ecosystem of the state had been devastated by this enormous flood. This catastrophic event also blemished the natural habitat of Vembanad lake, the largest lake in Kerala. The molluscan bed in the Vembanad lake is extremely diminished by the flood event of 2018. The siltation and sediment deposition after the flood was responsible for the damage to the molluscan bed, dispersal of molluscan species, and stagnation. In this study, we mainly focused on the vulnerability assessment of bivalve species, particularly Clams, and Mussels in the Vembanad lake. For the assessment of vulnerability, we evaluated the species distribution and sediment transport index of Vembanad lake. Data on species distribution were compiled from a survey that was carried out during the field visit to the sample stations. The satellite image of Cartosat 1 was downloaded from the Bhuvan NRSC portal for the estimation of the Sediment Transport Index (STI). The satellite image was processed and a vulnerability map is prepared using the geoprocessing software ArcGIS Pro. Most of the fisherman communities in the Ernakulam district of Kerala entirely depend upon the Clam fishery of Vembanad lake. According to the survey and analysis from the geospatial technology, it was found that the excessive sediment and slit deposition after the 2018 flood made the Mollusca in the Center of Vembanad lake more fragile. The present study shows that the STI has an impressive role in species distribution and the molluscan species are unfortified in the areas where a high sediment transport index was noticed.

Keywords: Remote sensing, GIS, Mollusca, Benthic community, Bivalves, STI

Time series analysis of coral reef area in shallow water off the coast of Ranghat area in Andaman and Nicobar Island using Sentinel-2 MSI data

[ABS-07-0342]

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Coral reefs are one of the most diverse marine ecosystems, commonly called the "Rainforests of the Sea. Though they only occupy less than 1% of the ocean floor, they are home to 14% of marine species by supplying food and shelter. The Status of Coral Reefs of the World 2000 report estimates that 27% of the world's coral reefs have been effectively lost due to human activities and climate impacts. Regular surveillance and conservation measures must be taken for this ecosystem to survive in a healthy state. To gather data, Surveys conducted underwater in shallow water are used by scientists and coastal managers to assess coral reef health and area, catalog threatened or invasive marine species, and support regional monitoring efforts. However, in-situ field studies are very costly and time-consuming, so optical remote sensing can be an effective alternative to monitor coral habitats. Due to its superior spectral and spatial characteristics, the Sentinel-2 mission has promising uses in coral reef mapping. A K-means classification was performed using remote sensing reflectance retrieved from Sentinel 2 MSI Top of the Atmospshere (TOA) radiance data to classify the coral and sea grass pixels from the deep-water pixels. From the Remote sensing reflectance, the bottom reflectance has been derived using a Quasi analytical algorithm and it has been used to do another classification using a threshold of 0.005 on the Bottom Reflectance at 560 nm. Both classifications have been carried out over the study area of Andaman Islands in order to perform the time series analysis of the coral reef area off the coast of Ranghat region which comprises the middle Andaman where coral bleaching is quite high. We can see a substantial decrease in the coral area over the year from 2017 till February 2023 except in 2021 this anomaly has been correlated with possible causative factors like Sea Surface Temperature, Chlorophyll-a Concentration, Calcite Concentration, and other Anthropogenic stresses, etc.

Keywords: coral reef,surveillance, Sentinel-2,K-Mean classification

Distribution of diatoms in the deep Indian Ocean

[ABS-07-0137]

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In the open ocean, diatoms form the dominant phytoplankton group and are abundant both taxonomically and numerically in the sun-lit zone. In comparison to euphotic depth, the information on diatom distribution below photic depth in the deep ocean is limited despite knowing the prevalence of diatom sinking in deeper waters across the global ocean. In this study, the diatom (>100µm) distribution in deeper water up to 5000m in the equatorial and southern tropical Indian Ocean was evaluated from the multiple plankton net samples collected during the spring inter monsoon season (March to May 2021). This study reports for the first time the presence of intact phytoplankton cells (>100 µm) in all vertical zonation (up to 5000m depth) beyond the photic zone in both the equatorial and southern tropical Indian Ocean. However, the cell abundance decreased in deeper depths. Diatoms are abundant in depths of >500m followed by dinoflagellates. Among the diatoms, the counts of centric diatoms are higher followed by pennates. Community comparison across all depths revealed that only a few species were found in the upper as well as deep ocean indicating the prevalence of fast sinking mechanisms. However, their contribution at respective depths differed. For instance, Asterolampra sp. contribution to the total community was ~7% and 45% in the upper and deeper (2500m-4000m) water, respectively. This study provides a basis to identify the community which can aid in deep ocean biogeochemistry studies.

Keywords: Diatoms, centrics, pennates, deep ocean, Indian Ocean

Assessing Fisher's Traditional Ecological Knowledge for Conservation of Electric Rays of India

[ABS-07-0110]

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Electric rays are the least studied group of elasmobranchs. Though not targeted, yet form a significant portion of bycatch. Little information exists about their ecology and biology. Fisher's traditional ecological knowledge can fill knowledge gap for these historically data-deprived fishes. Hence, here, we assessed attitudes and perceptions of artisanal fishers towards electric rays' conservation. We gathered information on catch frequency, seasonality, population trends, post-capture usages, and socio-economic values through semi-structured questionnaires survey. We interviewed 243 fishers at 15 artisanal villages in three states: Tamil Nadu, Andhra Pradesh, and Odisha, along east coast of India. The survey data was scrutinized, sorted into various categories: demographics, fisheries, and fisher's traditional knowledge, analysed and visualised as graphs and figures. We also presented qualitative information as general statement or quoted specific comments to better explain our findings. We found that fishers were well aware of electric rays and their electrical discharge. The data indicated that fishers knew the habitat in nearshore sandy bottoms. They get electric rays in their bottom-set gill nets. In general, December, January and February have high electric ray catch. Post-capture usage includes take-home consumption, discarding them dead, releasing them alive, and sell to poultry. Fishers discussed health benefits of electric ray's consumption. They perceived a downward trend in population due to anthropogenic influences: overfishing, pollution and climate change. Fisher's knowledge and scientific contributions can help develop management plans and conservation strategies. Initiating awareness campaigns within fishing communities and coastal citizens foster positive attitudes, thereby enhancing the electric ray's conservation.

Keywords: Elasmobranchs, Torpediniformes, Traditional Ecological Knowledge, Marine conservation, Indian fisheries.

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Extreme sea level changes in the North Indian Ocean- A review
[ABS-08-0042]

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Extreme sea levels, resulting from storm surges and high tides over the background mean sea level, are crucial in coastal regions. Changes in extreme sea levels can be caused by changes in mean sea level, storminess or tides. A review of extreme sea level changes is made based on the literature available up to 2021 . Causative factors such as mean sea level changes and changes in storminess contributing to changes in extremes have been discussed. The past studies in the north Indian Ocean, especially along the east coast of India, head of the Bay of Bengal and the Red Sea based on analysis of hourly tide-gauge data and numerical model hindcast are discussed. Along the east coast of India, the results indicate that changes occur in different time scales, varying from seasonal to interannual and long-term changes, which are found to be consistent with changes in mean sea level.

Keywords: Extreme Sea level, east coast of India Red Sea

Representation of mean state and variability of dynamic sea level and its projections for the Indian Ocean in CMIP6 models

[ABS-08-0177]

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The Indian Ocean (IO) coastline which houses a large population from the continents of Africa, Asia and Australia is vulnerable to a plethora of climatic hazards that are brought on by sea-level rise. The global mean sea level has risen at a rate of ~3.6 mm/yr over the last two decades and is projected to increase by more than 1m by the end of this century. A thorough assessment of the dynamics of the regional sea-level change is vital for effective policymaking to mitigate natural calamities associated with the rising sea levels. We use a suit of 27 models from phase six of the coupled model intercomparison project (CMIP6) simulations to study their representation of dynamic sea level (DSL) and the factors that influence DSL variability in the basin. We show that the multi-model mean DSL exhibits a good correlation with observation with few notable biases consistent across the models. There is a positive bias in the DSL across the basin with a west to east gradient and a pronounced bias in the Antactic circumploar current region. In the case of variability, most of the models underestimate the variability across the basin except the eastern equatorial IO. The poor representation of the equatorial winds in most models produces an Indian Ocean Dipole (IOD) like bias and results in the misrepresentation of climatic modes. Our analysis suggests that a finer horizontal resolution of the ocean component alone cannot guarantee a better representation of the DSL but requires proper representation of wind fields as well. A subset of best performing models among the ensemble is selected to have a more representative estimate of DSL change in the Indian Ocean. The Arabian Sea is expected to experience higher sea level rise (~35 cm), compared to the Bay of Bengal and the southern tropical Indian Ocean under a high emission scenario by the end of 2100. This research aims to gain better insights on the DSL evolution and its future projections in the Indian Ocean and to investigate the model deficiencies associated with the same.

Keywords: Dynamic Sea Level, Climate modes, Indian Ocean dipole, Global warming, Emission scenarios

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Shoreline retreat of sandy beaches under predicted sea level rise; A case study for Kerala coast

[ABS-08-0420]

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Sandy beaches that provides major ecosystem and economic services are under threat of erosion and is expected to enhance under the rising sea level scenario. Estimation of the likely erosion of beach under the changing climate holds its importance in designing the adaptive coastal management plans. We estimated the shoreline retreat of sandy beaches along the state of Kerala, southern Indian coast, based on Bruun rule that predict the changes in the active beach profile under sea level rise. Here we have used the beach profiles estimated using ICESAT-2 data and merged with coastal bathymetry from the hydrography charts to represent the active beach profiles. Along the Kerala coast, active beach profiles of 31 sandy beaches are generated and the possible shoreline retreat that can be caused under the 4 RCP (Representative Concentration Pathway) scenarios have been estimated based on Brunn rule. A complete erosion of the sandy beaches along the central Kerala coast is expected under RCP 8.5, where Kappad beach at Kozhikode is the most vulnerable beach and is predicted to erode completely even under the RCP 2.6. Beaches located to the southern part of Kerala are relatively less vulnerable, with less than 50% of shoreline retreat under RCP 8.5. Estimation of beach loss under predicted sea level rise critically depends on the slope of the active beach profile. The relatively steep slopes of the active beach profiles along the southern parts of Kerala state makes the region less vulnerable to sea level rise induced beach erosion. Under the changing climate scenario, the prediction of shoreline regression helps to ensure the need of supporting the coastal community. As the Kerala coast is densely populated, identifying the coastal regions susceptible to extreme erosions with the changing climate has its importance in managing the livelihood.

Keywords: Shoreline Regression, Brunn Rule, RCP (Representative Concentration Pathway), Active Beach Profile

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Assessment of sea level rise over Bay of Bengal and Arabian Sea

[ABS-08-0434]

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Coastal regions are threatened by Sea Level Rise (SLR) and its implications. Considered as one of the direct consequences of climate change, SLR varies from one location to another. The study aims to evaluate the past variation of SLR over Bay of Bengal and Arabian Sea. The study uses (i) Satellite measured Sea Level Anomaly (SLA) record (ii) General Circulation Model (GCM) simulated sea level (iii) Sea level contribution from Glaciers and Ice Sheets (iv) Local observed sea level and Global Mean Sea Level (GMSL) to critically examine the spatial variation of SLR over Bay of Bengal and Arabian Sea. The SLA measured by the satellites from the year 1993 until now is collected at different grid locations of Bay of Bengal and Arabian Sea. Also, GCM estimates of sea level is obtained following both 5th and 6th Assessment report of Intergovernmental panel on Climate Change (IPCC) separately. Furthermore, the spatially varying contribution of sea level from Glaciers and Ice-sheets over Bay of Bengal and Arabian Sea is estimated using the concept of sea level fingerprints. These four different estimates of historical sea level is used to study the past spatially varying SLR. Different estimates of sea level obtained over Bay of Bengal and Arabian Sea are tabulated and compared. The spatially varying trends of sea level are estimated. The study reveals, the trends of sea level over Bay of Bengal are observed to be higher as compared to Arabian Sea. The average estimated trend of SLR obtained was about 3.2 mm/year (between the years 1993 to 2023) over Bay of Bengal. In Arabian Sea maximum trend of about 2.5 mm/year is obtained. The study also demonstrates the deviation of local sea level rise of Bay of Bengal and Arabian Sea from GMSL. The rate of SLR over both Bay of Bengal and Arabian Sea is lesser than the Global SLR (about 3.3 mm/year, reported by IPCC). Hence, the use of location-specific sea level for planning coastal zone activities is emphasized.

Keywords: Sea Level Rise (SLR), Sea Level Anomaly (SLA), General Circulation Model (GCM), Intergovernmental panel on Climate Change (IPCC), Bay of Bengal, Arabian Sea

Variability of ocean heat content

[ABS-08-0233]

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Oceans, a major component of the global climate system, covers about 71% of the earth's surface. The presence of greenhouse gases in the atmosphere, such as carbon dioxide, methane, water vapour etc., acts as a blanket that traps long wave radiation emitted from the earth's surface, thus making it habitable. However, increased storage of greenhouse gases during the past few decades has affected the climate system of the earth in all spheres such as increased warming, sea level rise etc. The oceans, because of their high specific heat capacity, absorb the excess heating of the atmosphere and store the heat mostly in the upper layers of the oceans leading to an increase in the ocean's heat content. The energy received by the ocean which is stored as internal energy or enthalpy is referred to as ocean heat content (OHC). The upper ocean heat content in all the oceanic regions were found increasing since 1960. In this study, the upper ocean heat content was estimated using temperature and salinity data obtained from the Met Office Hadley Centre for the period 1960 to 2020. All the three major oceans showed an increasing trend in the ocean heat content but with different rates. One notable feature is the decrease in the heat content during the period 1980-83 as a common to all the three tropical oceans. To understand the regional differences in the warming rate of the Indian Ocean, the heat content trend was calculated for six sectors and their temporal variability was studied. Further, the ocean heat content was also estimated for different depth ranges to understand the warming rate of surface and subsurface waters. Among all the regions, the Arabian Sea shows the highest rate of heat content storage.

Keywords: ocean heat content, greenhouse gases

A study of ocean heat content with seawater potential temperature using CMIP6 models in the Bay of Bengal

[ABS-08-0120]

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Over the past few decades, the Indian Ocean has been warming faster than the other ocean with a significant impact on regional climate, coastal communities, and marine ecosystem. The current study aims to represent the Ocean Heat Content of six different global climate models from Climate Model Intercomparison Project Phase 6 (CMIP6) in the Bay of Bengal. The lack of data has always made it difficult to accurately assess both physical and biological oceanographic factors. It is a major issue in BoB because there aren't many field explorations, thus modeling is required to make up for the deficiency. The Bay of Bengal is highly dynamic in nature, and due to its versatile nature, it is very difficult to analyze the seawater properties. The region is highly influenced by monsoons, winds, currents, and freshwater influx which affect the regional climate. The Seawater Potential Temperature (Thetao) of the six best-performing models up to a depth of 500 m from the sea surface is chosen for the study on a 1° x 1° geographic and monthly temporal scale. The performance of each model is compared against RAMA buoy and NIOA data. On seasonal and monthly climatology scales, the Ocean Heat Content is evaluated and annual trends were obtained. Performance indices including correlation coefficient, root mean square error, average error, and absolute average error were calculated. Out of 6 models, GISS-E2-1G shows less bias over the entire region. The RAMA Buoy data taken for the location (15oN 90o) is compared with selected CMIP6 models and inferred that the model values are higher than the in-situ observational values. The study provides a deep understanding of how the Ocean Heat Content is varying in the Bay of Bengal over the years seasonally and annually.

Keywords: Bay of Bengal, CMIP6, Ocean Heat Content, Sea water Potential Temperature

Changing the dynamic patterns of the Thoothukudi group of islands to sea level rise by remote sensing-based approach

[ABS-08-0205]

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The Thoothukudi group of islands provide a valuable window into the future impacts of global sea level rise because these islands typically form narrow and low-lying lands that are commonly perceived to be particularly vulnerable. Nevertheless, the limited study on the reef islands in the Thoothukudi suggests that the primary cause of shoreline changes and inundation to date results from extreme events and sea level rise. This study investigates the quantitative analysis of long-term changes in the island area and its shoreline over the past 50 years as determined by Landsat images using a Geographical Information System (GIS). According to the altimetry data of the Thoothukudi, the local sea level has risen at a rate of 1.26 mm per year. Results highlight that the islands: Kariyachalli (11.4ha), Koswari (9.3 ha), and Vaan (16 ha) have completely decreased their land area. At the same time, it is noticed that the islands were migrating towards the north due to the sedimentation process. This study suggests that the islands are highly dynamic features which will continue to change their positions over the next century. These findings present new opportunities for low-lying islands to conserve and manage the resources affected by sea level rise.

Keywords: sea level rise, Thoothukudi, Landsat images, Inundation and Sedimentation

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Relationship between coral bleaching and large-scale oscillations in the Lakshadweep archipelago
[ABS-08-0063]

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The coral reef ecosystems in the Lakshadweep Sea are least studied due to its limited in-situ measurements. The objectives of this study were to compare the remote sensing datasets with the available in-situ measurements and confirm the reliability of these datasets for further studies in this region and also focuses on how the sea surface temperature and salinity triggered coral bleaching during El Niño Southern Oscillation (ENSO) /Indian Ocean Dipole (IOD) events. We found that satellite observations of sea surface temperature (r=0.94) and sea surface salinity (r=0.81) well correlated with in-situ measurements respectively. Such a high degree of correlation enabled us to analyse satellite data for inter-annual variations like ENSO and IOD. Coral bleaching due to salinity variation was found to be negligible. The study delineates a coral bleaching threshold temperature and the prevalence of such warm waters in the coral environment. Analysis revealed a mass coral bleaching peak during the El Niño event in 2016, with a maximum prevalence of 78 days. Similarly, high coral bleaching events were observed in 2010 (El Niño; 63 days) and 2019 (PIOD; 56 days). Compared to other seasons, the maximum temperature was noticed during the sprig inter-monsoon (March to May). But from 2015, intense warming in the coral region was also noticed in the fall inter-monsoon (October). Combined with global warming, this trend of thermal stress toward coral bleaching may continue in the long term, which will negatively impact the health of coral ecosystems.

Keywords: Coral reefs, Bleaching threshold, SST, El Niño, IOD, Lakshadweep Islands

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Chemical profiling of UV absorbing Mycosporine like amino acids from coral dinoflagellates of Lakshadweep atolls figuring out a mitigation strategy for upcoming events of coral bleaching.

[ABS-08-0090]

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Marine organisms are known to have evolved to live in a wide range of habitats and are functionally adapted to extreme conditions which induce the production of a wide array of secondary metabolites in them as a means to maintain their homeostasis in stressful conditions. Mycosporine-like amino acids (MAAs) are a class of recently reported secondary metabolites with multiple functions, including the protection of living cells from UV ray-induced damage. Several studies from the coral reefs around the world reported higher concentration of MAAs in corals during unfavorable conditions as a survival tactic which can be an indication of the upcoming bleaching events. The Lakshadweep atolls remains less explored in such researches and this study aims at the profiling of MAAs from the coral associated dinoflagellates in the reefs of the archipelago. Samples collected from the islands Kavaratti and Kadmat are subjected to analytical procedures to detect and confirm MAAs. Preliminary spectroscopic confirmation and the subsequent HPLC of the samples revealed the presence of about 9 different compounds, 3 of which are previously described from similar ecosystems like Great Barrier Reef, Australia. The unknown compounds are to be further purified and analyzed using advanced chromatographic and spectrometric techniques. Since the UV protection factor of various MAAs differs each other, the identification of exact compound can help in assessing the capacity of the particular organism to tolerate an extreme condition. Also, the identification of coral species which produce comparatively higher concentration of MAAs will help in setting up of climate resilient coral hatcheries and nurseries. So, the profiling of MAAs will be a promising methodology to figure out mitigation strategies for coral bleaching in this context of varying climate. So far, no similar works are reported from the coral reefs of Lakshadweep, making our results to be a first report in this aspect.

Keywords: Mycosporine-like amino acids (MAAs), Coral bleaching, Lakshadweep atolls, Climate change

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Climate modes of tropical Indian Ocean and their tele-connections

[ABS-08-0442]

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The Indian Ocean Dipole (IOD) is a significant climate phenomenon characterized by varying sea surface temperatures (SSTs) between the western and eastern regions of the Indian Ocean. It undergoes positive, neutral, and negative phases. During positive IOD episodes, the western Indian Ocean experiences warmer-than-average SSTs, while the eastern Indian Ocean has cooler-than-average SSTs. This leads to increased rainfall over the western Indian Ocean and severe drought in the eastern Indian Ocean, impacting countries like Indonesia and Australia. Negative IOD events have the opposite effect. Climate modes such as the IOD and the El Nino Southern Oscillation (ENSO) greatly influence the climate variability of the tropical Indian Ocean and have significant implications for rainfall patterns, floods, droughts, and the marine economy of the surrounding regions. Therefore, it is crucial to study and understand these climate modes and their interrelationships. Previous research studies have identified conventional IOD events with a dipole structure and unconventional IOD events called the Indian Ocean Tripole (IOT), characterized by warming in the central and cooling in the eastern and western regions of the Tropical Indian Ocean. Although the association between IOD and ENSO has been extensively investigated, the connection between IOT and ENSO remains less explored. This study aims to enhance our understanding of the climate mode IOT and its relationship with ENSO. To investigate these climate modes, the study utilizes important climate indices including the Dipole Mode Index (DMI), Nino 3.4, and Tripole Mode Index (TMI). Correlation analysis revealed a moderate positive correlation of 0.43 between TMI and Nino 3.4, while the correlation between DMI and Nino 3.4 was found to be 0.40. Further results and spatio-temporal characteristics of these climate modes will be discussed in the paper, providing a comprehensive examination of the dynamics of the IOD, ENSO, and IOT.

Keywords: Indian Ocean Dipole, El Nino Southern Oscillation, Indian Ocean Tripole

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Identification of gas flares using remote sensing techniques

[ABS-08-0095]

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Gas flares produced during petroleum extraction will impact the environment, harm human health, and also drive climate change that will have negative impacts. Iran ranks third in natural gas production and also gas flaring volumes and most of them are located in coastal and offshore regions of the Persian Gulf. Pollution from gas flaring in this region endangers the ecosystem seriously. The unavailability of official information on volumes and locations of gas flares hindered the efforts for the evaluation of gas flaring in the surrounding environment. Estimation of the locations of these flaring activities will be laborious by the conventional surveys. Literature suggests that there are few remote sensing techniques available for the estimation of gas flaring activities. The current study is an attempt to develop an improved remote sensing technique to identify the locations of gas flares using the indexing approach. The developed technique, Normalized Differential Flare Index (NDFI) uses the Landsat-8 Operational Land Imager Blue and Shortwave Infrared (SWIR) bands to detect active gas flares in the given satellite image. The results of the study were evaluated with available sources and found accurate in identifying flare locations available in each scene. These results are highly useful in environmental management and planning. It also provides a vital basis for pollution control agencies to take appropriate measures.

Keywords: Gas Flare, Remote Sensing, environment, pollution, NDFI, Oil and gas

Study of prevalent distribution of thermotolerant Symbiodiniaceae in sea anemones and its effect in countering the anthropogenic impact in the Andaman Sea.

[ABS-08-0124]

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The corals are the most diverse ecosystem, providing significant ecological and economic value to the community. The foundation of coral reefs depends on the mutualistic bond between the photosynthetic dinoflagellate of the family Symbiodiniaceae and the host. This interconnection drives cooperation which enables stability and sharing of resources. The predominant rise in anthropogenic effect has led to hindrances in the coexistence of Symbiodiniaceae within the host. The current study focused on examining the ecological role of Symbiodiniaceae in the coral reef, their interaction with the host, and the molecular aspect of the relationship. The analysis of molecular diversity within two Sea anemones and in one Zoanthus species, Anthopleura elegantissima, Stichodactyla gigantea and Zoanthus SP, showed an overall high abundance of Cladocopium, Symbiodinium and Durusdinium species. The uncultured Symbiodiniaceae genera within the relevant organism were sequenced using the Illumina Miseq platform with targeted metagenomics. The distribution of Symbiodiniacese in A. elegantissima, included Symbiodinium (37%), Cladocopium (35%), unclassified Symbiodiniaceae (24%) and Durusdinium (4%). But Cladocopium (50%) was found to be more dominant in S. gigantea than Symbiodinium (23%), with unclassified Symbiodiniaceae (14%) and Durusdinium (13%). About 33% of species in Zoanthus were Symbiodinium and Cladocopium, followed by unclassified Symbiodiniaceae (23%) and Durusdinium (11%). The general distribution of Durusdinium in all three species exhibits a promising bleaching recovery with the temperature hikes. The present study also characterised the occurrence of the microbiome in association with Symbiodiniaceae. Thus understanding intercommunication between symbionts will help to uncover their resilient nature and further help to preserve their integrity and unique biodiversity.

Keywords: Coral-Bleaching, Symbiodiniaceae, Thermotolerant, Microbiome, Anthropogenic effect

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Holocene paleomonsoon reconstruction during Holocene from southern Saurashtra, Gujarat-A geochemical approach

[ABS-08-0060]

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The Indian monsoon system is a low-latitude process which is dynamically linked with the lateral migration of the intertropical convergence zone (ITCZ). Even though the Indian monsoon responded in accordance with the natural forcings and climate variables, yet its association with the global climate dynamics is seldom understood. The present study aims to delineate the paleohydrological conditions as a function of the Indian monsoon from the western India that dominantly witness the Indian summer monsoon (ISM). The southern Saurashtra, western Gujarat witness seasonal rivers that gets activated during ISM and thus the region provides an ideal platform to investigate the past ISM variability vis-à-vis paleoclimate conditions. A sediment core (~65 cm) retrieved from the mudflats of southern Saurashtra (Jaffrabad) was studied for various geochemical proxies and chronologically supported by four AMS radiocarbon ages. The study demonstrated a warm and humid climate as a result of strong ISM during 10650-5500 cal yr BP associated with the solar as well as orbital forcings. The weak monsoon during 5500-2700 cal yr BP has been linked with comparative migration of the Intertropical convergence zone (ITCZ) southward along with the increased El Nino like conditions. Further the wavelet analysis depicted prominent periodicities of ~1024 yr, ~512 yr and ~256 yr illustrating a crucial role of solar forcing on the mudflats of Saurashtra, western India. By reconciling the geochemical proxies, the present study has implications on paleomonsoon reconstruction and establishing the possible linkage of ISM with the global climate system during the Holocene epoch.

Keywords: Indian summer Monsoon, Intertropical convergence zone,Holocene,mudflat sediment,southern Saurashtra,Geochemical Proxies

Characteristics of extreme rainfall associated with Indian summer monsoon under climate change scenarios.

[ABS-08-0180]

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Identification of extreme rainfall events during the Indian summer monsoon (ISM) season had its importance since the start of the Anthropocene era. Using a set of identified high-fidelity CMIP6 models, we quantified the changes in the characteristics of extreme rainfall events during the ISM season for mid-century (2030-2064) and end-century (2065-2099) and for four climate change scenarios, viz., SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5. These are the top priority tier 1 scenarios of Coupled Model Intercomparison Project 6 (CMIP6). The spatial variability of mean and extreme rainfall events is identified and was found to increase the most under the warmest scenario. The changes in the intensity and frequency of very extreme rainfall events were found to increase the most with a large inter-model spread. Further, we found the dependence of atmospheric water holding capacity to increased temperatures (as given by the Clausius Clapeyron (CC) relation), which describes much of the changes in extreme rainfall intensities at warmer atmospheric states. We found a near CC and negative CC scaling over the north and south Indian regions, respectively, which was found to increase with the rate of warming. The physical characteristics of extreme events were identified to delineate any changes in the relationship between extreme rainfall events and air temperature. Such regional-scale information will help in identifying regions of potential heavy rainfall in future. Our study concludes that even with a scenario that follows a road of sustainability with a commitment to achieve the goal of mitigation with few challenges, it is nearly impossible to reverse back the changes that have already happened with respect to extreme weather events and that the intensity and frequency of extreme rains will eventually increase.

Keywords: Indian summer monsoon, extreme rainfall events, CMIP6, climate change scenarios

Basin-wide warming alters phytoplankton in the oligotrophic waters of the eastern Arabian Sea during the summer monsoon

[ABS-08-0078]

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In a climate change scenario, it is crucial to comprehend how the warming oceans alter phytoplankton and its response in a highly productive basin like the Arabian Sea (AS). We explored the effect of warming on the latitudinal variation (8-21°N, along 68°E) of phytoplankton response in the sunlit zone (0-60 m depth) of the eastern Arabian Sea during the southwest monsoon (SWM-2020). The sea surface temperature (SST) was extremely warm (>28 °C), with the elevated temperature being profound in the northeastern AS (>30 °C), pointing to decadal warming due to the highest positive Indian Ocean Dipole since the 1980s. The active Findlater jet-induced (FJ axis, 15-17 °N) wind stress curl modulated the mixed layer depths (MLDs), causing shallower MLDs to the north AS (positive wind stress curl) and deeper MLDs to the southern AS (negative wind stress curl) during SWM. The higher SST-induced stratification weakened vertical mixing and exacerbated dissolved inorganic nitrate+nitrite limitation in the upper 30 m depths. Consequently, the high DSi: DIN and low DIN: DIP ratios resulted in lower phytoplankton biomass and favoured the niche for dinoflagellates over diatoms. The presence of warm-tolerant dinoflagellates Oxytoxum, Gymnodinium, Gyrodinium, and Heterocapsa, were remarkably high. The observed ratio also favoured diazotrophs to thrive, including the free-living Richelia intracellularis and diatom-diazotrophs associations (DDA). DDA was primarily dominated by Richelia-Rhizosolenia in the warm, N-depleted mixed layer where shallower nitracline coincides with the northern AS. Concurrently, the occurrence of Crocosphaera - Climacodium in the open-ocean region of the southern AS implicit the favouring niche selection of DDA could be contingent on their less iron requirement and host availability. The stratified N-limited mixed layer resulted in forming subsurface chlorophyll maximum (SCM, between 40-60m) coinciding with nutricline,

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except in southern stations where deeper MLDs were profound. In general, SCM were pervaded with large pennate and centric diatoms. In contrast to earlier beliefs that AS is unfavourable to DDA or UCYN-B (Shiozaki et al., 2014), their presence and ecological interactions in our observations along the warm oligotrophic waters indicate it could play a crucial role in the biogeochemical cycles of the eastern Arabian Sea.

Keywords: Phytoplankton, warming, Diazotroph, Diatom-Diazotrophs, Eastern Arabian Sea

Impact of global warming on regional ocean circulation and Air-sea interactions over the Bay of Bengal.

[ABS-08-0227]

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Recent studies, such as Roxy et al. (2020), have reported rapid warming in the Indian Ocean during past two decades. The warming of Ocean can increase the surface ocean heat content and could impact the air-sea interactions thereby modulates the weather and climate events. It is important to understand the regional changes in Physical Oceanographic parameters and air-sea interactions in the context of global warming. Bay of Bengal being an integral part of Indo-Pacific warm pool zone plays a vital role in regional (Indian Ocean) climate. The objective of this study is to understand the impact of Indian Ocean warming on the changes in the regional circulation patterns, air-sea interactions, particularly over Bay of Bengal. In the context of Ocean warming, we have examined the prominent changes in distinct Ocean parameters viz, sea surface temperature SST, mixed layer depth, Isothermal layer, D20, sea surface height (SSH), sea surface salinity and Ocean circulation patterns. The study uses ORAS5 (Ocean Reanalysis System 5) and the observed changes in Bay of Bengal physical Oceanographic characteristics with respect to global warming is reported and its probable impact on modulated air-sea interactions is discussed.

Keywords: Global Warming, Regional Changes, Bay of Bengal, Air-Sea Interactions, Physical Oceanographic Parameters

Intercomparison of tropical Indian Ocean currents in various reanalysis products and the assessment of CMIP6 models.

[ABS-08-0116]

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Tropical ocean currents play a major role in the distribution of mass and heat, thus playing a crucial role in the regional weather and climate. Here, we focus on the intercomparison of Ocean currents in the tropical Indian Ocean using various reanalysis products such as Ocean Reanalysis System 5 (ORAS5), Estimating the Circulation and Climate of the Ocean (ECCO), Global Ocean Data Assimilation System (GODAS), Ensemble Coupled Data Assimilation (ECDA), the Bluelink Reanalysis (BRAN) and Simple Ocean Data Assimilation (SODA) with reference to in-situ observations and the satellite-derived product OSCAR (ocean surface current analyses real-time) in the Tropical Indian Ocean (TIO). The reanalysis products represent the mean state of surface circulation realistically; however, biases are evident across the basin, particularly in GODAS, ECCO, and ECDA products. The strength and location of the equatorial dominant flow; Wyrtki jets are underestimated by all the reanalysis products. Among all the six reanalysis products, BRAN is most skillful in representing the surface circulation of TIO, followed by ORAS5. The vertical extension of subsurface seasonal maxima of zonal currents over the equatorial Indian Ocean is well captured in ORAS5 compared to the rest of the reanalysis products with respect to in situ measurements. In addition to reanalysis, we further assessed the surface currents simulated by 45 climate models that participated in the latest version of Coupled Model Intercomparison Project (CMIP6) models. The models NorESM2-MM, CESM2-WACCM-FV2, E3SM-1-1-ECA, CESM2, and CESM2-FV2 are found to be the five best-performing models for the TIO region in representing the surface circulation with reference to the OSCAR product. The present study advocates the importance of understanding the ability of the coupled models in representing the tropical Indian Ocean surface circulation and their impact on the regional weather and climate.

Keywords: Tropical Indian Ocean, zonal currents, reanalysis, OSCAR, CMIP6

Role of oceanic internal variability in the interannual-to-longer timescale in the Indian Ocean

[ABS-08-0221]

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The interannual-to-longer timescale (also referred to as low-frequency) variability in sea surface temperature (SST) of the Indian Ocean (IO) plays a crucial role in affecting the regional climate. This low-frequency variability can be caused by surface forcings and oceanic internal variability. Our study utilizes a high-resolution global model simulation to investigate the factors contributing to this observed variability and finds that internal oceanic variability plays a crucial role in driving the interannual to longer timescale variability in the southern IO. While previous studies have explored the impact of internal variability in the Indian Ocean, they have primarily focused on the tropical basin due to limitations imposed by the regional setup of the models used. However, our analysis reveals a notable southward shift in the latitude band of active internal variability for the interannual to longer period compared to earlier estimations based on coarser Indian Ocean regional models. By conducting an energy budget analysis, we show that baroclinic instability serves as the primary driver of the internal variability. This instability results from the modulation of isothermal tilts caused by the vertical shear of geostrophic zonal currents. It leads to an unstable upper water column, thereby enhancing the eddy kinetic energy (EKE) in the region. The slowly growing baroclinic instabilities, characterized by longer time and length scales, facilitate the generation of Rossby waves, which propagate the signals of SST and sea-level anomalies westward.

Keywords: internal variability,low frequency variability,baroclinic instability,Rossby waves

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Increasing intensity of heat waves over India in the recent years

[ABS-08-0148]

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India has severe heatwaves from March through June. Under a warming climate in India, heatwaves that cause catastrophic harm have increased and are expected to occur more frequently. A heat wave is a period of unusually high temperatures and high humidity. From a statistical point of view, a small change in the mean value of a climate variable (such as temperature) corresponds to large changes in weather, which means a small shift in the mean of the temperature distribution implies a sizeable change in the frequency and intensity of temperature extremes. In this paper, the observed patterns and statistical analyses of the temperature variability across India are discussed. For the base period of 1981¿2022, the anomaly of 2metre temperature, outgoing longwave radiation(OLR) , and vertical velocity is computed. The heat wave was identified using the criteria given by the India Meteorological Department (IMD), i.e., a heat wave is recognised when the daily normal maximum temperature of a station is less than or equal to (greater than) 40 °C, and it will be considered a heat wave if the daily maximum temperature exceeds the daily normal maximum temperature by 5 °C (4 °C). The analysis was confined to the three summer months of March, April, and May. The standard deviation of daily temperature for May over the years 1981¿2022 shows large values extending from the north to the interior peninsular, apart from the coastal regions facing the Indian Ocean. The temperature anomalies show positive departures in those regions. The vertical velocity shows anomalous sinking over the Indian landmass due to the anomalous anticyclone over the region. The sinking motion causes positive OLR anomalies, resulting in heatwaves over the region.

Keywords: heat waves; temperatures; climate change; statistical analysis

Processes governing the climatic variability of the thermohaline structure of the upper ocean over the south-eastern Arabian Sea

[ABS-08-0497]

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The Indian Ocean is distinct from the other two tropical oceans. Restriction of oceanic heat transport beyond 30°N and a reversible monsoon wind result in physical and dynamical changes to the circulation and tracers. In addition to these, the Indian Ocean has its own climatic mode, the Indian Ocean Dipole, which can impact the global climate via teleconnection. Besides, from an Indian point of view, the Indian Ocean is extremely significant because it can influence the Indian summer monsoon, which can affect the socioeconomic condition of the subcontinent. Due to climate change, the Indian Ocean is experiencing extreme anomalies. The western Indian Ocean is warming more quickly than the global average. This uneven distribution has the potential to alter ocean circulation, thereby influencing the Indian Ocean Dipole and other climate modes present in the Indian Ocean. Thus, climate change can also affect air-sea interactions, such as the monsoon system and tropical cyclones. In addition to this, other issues, such as coral bleaching and sea-level rise, are also consequences of climate change. In light of climate change, it is essential to investigate and report on any behavioural changes involving ocean processes and their variability. The monsoon's arrival in Kerala (MoK) is crucial because it brings monsoonal winds. According to studies, this MoK depends on the sea surface temperature (SST) over the southeastern Arabian Sea (SEAS), where a peculiar mini warm pool known as the Arabian Sea Mini Warm Pool (ASMWP) forms. The ASMWP formation mechanism is entirely distinct and independent from that of the Indian Ocean Warm Pool (ICWP). ICWP formation typically begins in the pre-monsoon season, whereas ASMWP formation begins in the winter and reaches maturity in May. This high SST water dissipates one week prior to the onset of the monsoon, which is primarily attributable to coastal upwelling. Once the summer monsoon has ended, the

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east India coastal current (EICC) transports the low-saline Bay of Bengal water to the southern tip of the Indian peninsula, from where the winter monsoon current (WMC) and west India coastal current (WICC) transport it to the seas. Once this low-salinity water reaches the SEAS, it overlies the Arabian Sea's high-salinity water and creates a salinity stratification of great prominence. Due to higher temperature diffusion, the isothermal layer depth (ILD) increases, resulting in the formation of a dense barrier layer. The barrier layer prevents water above the mixed layer and below the thermocline from mixing. As a result, the shortwave radiation becomes trapped in the upper few meters of the SEA, causing the SST to increase in pre monsoon season. In addition, an inversion layer forms beneath the mixed layer depth (MLD). According to studies, once vertical processes resume, the heat trapped in the inversion layer could increase the SST over SEAS once vertical processes resume. Due to these processes, the SEAS is the warmest oceanic region in May. Despite the formation mechanism's apparent simplicity and completeness, numerous studies have identified peculiar subsurface behaviour in this region. Using three years of in-situ data, a study determined the seasonal variation of the inversion layer during the winters of 2002-03, 2003-04, and 2004-05. According to it, the ILT is shallower during the 2003-04 winter season compared to the 2002-03 and 2004-05 winter seasons. In 2003-2004, the salinity decreased due to the increase in BoB low saline water input. According to another study, the incidence of percentage inversion was lower in 2005-2006 than in other years. However, the salinity was lower at the surface. Recent research indicates that the heat stored in the barrier layer does not necessarily increase the surface temperature of the ocean. It is evident from the aforementioned studies that the dynamics of the SEAS are not yet fully understood. This region necessitates a long-term study to comprehe

Keywords: Southeastern Arabian Sea, Inversion layer, Convective mixing, Long term variability

ENSO and the increasing concentration of absorbing aerosols over the Indo-Gangetic plain in a changing climate

[ABS-08-0332]

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This study examines the influence of the El Nino Southern Oscillation (ENSO) on the transport, deposition, and distribution of aerosol concentration over the Indo-Gangetic Plain (IGP) from 2006 to 2022, a span of around 16 years. The analysis shows that the influence of El Nino and La Nina has decreased in determining the distribution and its movement. Previous studies until 2010 have shown that the ENSO causes an increase in aerosol concentration during El Nino and a decrease during La Nina. As a result, measured levels of AOD ought to indicate a rise during El Nino and a decrease during La Nina. However, the observation shows that the aerosol concentration is not affected by El Nino or La Nina. The AOD obtained shows high values even during the La Nina phase and lower levels during El Nino, indicating that there are other factors that depend on the concentration of aerosol in IGP. Strong winds across the Arabian Peninsula have been observed throughout multiple La Nina years, including 2008, 2020, and 2021. These winds aided in the long-range aerosol movement towards the IGP. This is accomplished by contrasting the meridional zonal wind trajectory with the backward wind trajectory. As a result, aerosol concentrations above the IGP rose even during the La Nina episode. The wind is stronger in the Arabian Peninsula during the 2015¿2016 El Nino, but it becomes weaker as it approaches India. The amount of aerosol decreased as a result of less long-range transport to the IGP.

Keywords: ENSO, Indo-gangetic plain, Aerosol optical depth

Asymmetric impact of the Atlantic Zonal Mode on ocean surface waves in the tropical Indo-west Pacific during boreal summer

[ABS-08-0264]

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We have investigated the impact of the Atlantic Zonal Mode (AZM) on ocean surface waves in the tropical Indo-west Pacific during boreal summer. We found that the AZM exerts significant influence on surface winds and thus waves, independent of ENSO, which tends to mask the effect of AZM. Particularly, a warm AZM induces surface wind anomalies that oppose the climatological winds. As a result, it reduces the wind sea in the Bay of Bengal (BoB), the South China Sea (SCS) and Philippine Sea (PS), and causes an apparent domination of southern ocean swells in the Arabian Sea. This is substantiated by consistent changes in the mean wave period and energy flux into waves. A warm AZM can favour marine operations in the BoB, SCS and PS. On the contrary, a cold AZM does not cause any significant change in the wave activity, giving rise to an asymmetric impact of AZM. Sensitivity experiments conducted using WAVEWATCH-III model support our results.

Keywords: Atlantic Zonal Mode,Ocean waves,Teleconnections,Marine operations,Indian Ocean

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Exploring the impact of Southern Ocean sea ice on the Indian Ocean swells

[ABS-08-0161]

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The present study delves into the impact of the Southern Ocean (SO) sea ice concentration on the North Indian Ocean (NIO) wave fields through swells using 6 years (2016-2021) of WAVEWATCH III (WWIII) simulations. Two sensitivity experiments based on forcing fields were done, one with SO sea-ice ($W3_{with\_ice}$) included as the forcing and the mandatory wind forcing, and the second run without sea-ice ($W3_{no\_ice}$) forcing. The analysis shows effect of the SO sea ice concentration on northward swell peaks in September-November, coinciding with the maximum sea ice extent in the Antarctic region of the Indian Ocean. When SO sea ice is ignored, simulations are biased more by ~ 60% and ~ 37% in significant wave height and period, respectively, against simulations with SO sea ice when compared with NIO mooring data. We have shown that the forecasts of the timing of high swell events along NIO coasts can be erroneous by ~ 12 h if the SO sea ice concentration is not included in the model. Further, W3 no_ice fails to simulate low-frequency swells that reach the NIO coast at a much slower rate and could potentially produce false swell alerts along southeastern Australian coasts. These results have large implications for operational oceanography. In summary, our study highlights the importance of the SO sea ice concentration inclusion in the wave models to accurately simulate NIO waves.

Keywords: Indian Ocean, Ocean waves, southern ocean,sea ice concentration,WAVEWATCH III,Wave Modelling

Evaluating surface heat and momentum fluxes in the Indian Ocean: A comparative analysis of reanalysis products and their temporal trends.

[ABS-08-0371]

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The global modeling community utilises atmospheric reanalysis products because of their high spatial and temporal resolution and long-term data availability. These products are necessary for carrying out model simulations, model spin-up, downscaling and even conducting an ocean state analysis. In this study, an assessment of temporal variability of air temperature (Ta), specific humidity (Qa), wind speed (WS), momentum flux (Mo), and net heat flux (Qn) available from seven atmospheric reanalysis products (TROPFLUX (TROF), OAFLUX (OAF), NCEP/DOE AMIP-II Reanalysis (NCEP), JRA55 do (JRA), ERA5 (ERA), MERRA2 (MERRA) and NCMRWF-IMDAA (IMDAA)) has been carried out across the Tropical Indian Ocean (TIO) against existing in-situ observations from RAMA and OMNI buoys moored at different regions of TIO. Additionally, we used CCMP wind product and an experimental daily heat flux product (SatFlux) to assess the capability of reanalysis products in reproducing the spatial seasonal variability for Mo and Qn. In the case of Mo in the Arabian Sea and the Bay of Bengal, TROF exhibits the highest mean correlation. All reanalysis products underestimate Qn across all seasons in the TIO. Examining long-term trends, Ta and Qa display a gradual increase over the past three decades over the TIO. The annually averaged WS in the southern Indian Ocean displayed the highest magnitude compared to central and northern Indian Ocean, surpassing 7 m/s. While Mo does not exhibit a notable long-term trend, there is a noticeable increase in its magnitude in the southern Indian Ocean. MERRA shows the highest annually averaged magnitude of Mo across all regions in TIO. Additionally, TROF is seen to display a positive trend in Mo over TIO. TROF and ERA indicate the highest magnitude of annually averaged Qn, which remained below 50 W/m2 in the last three decades. In comparison to the northern and central Indian Ocean, the southern Indian Ocean exhibits the lowest heat flux. This is primarily attributed to a notable rate of decrease in Qn with an average value of 0.3 W/m2 per year.

Keywords: Tropical Indian Ocean, Atmospheric Reanalysis Products, CCMP, Momentum Flux, Net Heat Fux

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Dynamics of ocean mesoscale eddies in the Bay of Bengal from 3-decades of satellite altimeter measurements

[ABS-08-0292]

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The mesoscale eddies in the Ocean represent the swirling of the ocean currents. Their dimensions may extend from 50-300 km and span for 10-100 days, and they are ubiquitous in the Ocean. Eddies play an important role in transporting heat, salt, momentum and nutrients, etc., and modulate the circulation patterns of the Ocean. The Satellite altimeter-based sea level (SLA) measurements have been in greater use to understand various aspects of ocean eddies. We have adopted an automatic eddy detection and tracking method following Pessini et al., 2018 using SLA from 1993-2022 to characterize and study the dynamics of the eddy properties, such as polarity, radius, associated kinetic energy, amplitude, and lifetime, in the Bay of Bengal (BoB). In this study, we aim to understand the spatial distribution of the mesoscale eddy characteristics and their dynamics in the BoB; for this purpose, we have analyzed the eddies with a lifetime of more than 5-days and a radius of 50-300km. It is observed that the eddies with short lifetime (5-30 days) are more dominant (90% of total eddies) and are mostly forming in the western BoB. Out of the total number of eddies detected in BoB, cyclonic eddies (53%) are more than anticyclonic eddies (47%). The eddies formed north of 12oN possess relatively high amplitude (~8-12 cm) and last for a long time (~50-80 days), but their spatial extension is less (~70-90 km). In contrast, in the southern part of 12oN (up to 3oN), the eddy is with reduced amplitude and annihilates relatively early, but they are bigger in size (>120 km).

Keywords: Sea Level Anomaly, Eddies, Mesoscale, Satellite altimeter, Bay of Bengal

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Observed trends in the satellite derived ocean surface currents for the major current systems of the Tropical Indian Ocean

[ABS-08-0289]

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Ocean surface currents represent the horizontal movement of the water in the surface layer of the Ocean (30 meters in this analysis). They play a significant role in transporting heat, salt, momentum, and plankton from one place to another place of the Ocean. As the space-based sensors cannot measure this parameter directly, specific diagnostic models were proposed to estimate the currents from different components of it, viz., geostrophic currents (from satellite altimeters), Ekman velocities (from Scatterometer based winds) and buoyancy-driven velocities (from Sea Surface Temperature). Following Bonjean and Lagerloef, 2002, we have estimated long-term (since 1993), gap-free, daily currents at 0.25o grid spatial resolution and are available to download from the NICES/Bhuvan portal of NRSC. These products are much more suitable for climate studies as they are long-term databases (span for three decades) and consistent in space and time. In this study, we have used these satellite derived ocean surface currents from 1993-2022 to examine the temporal trends of the major current systems of the Tropical Indian Ocean, such as West India Coastal Currents (WICC), East India Coastal Current (EICC), Somali Current (SC), Summer Monsoon Current (SMC), Winter Monsoon Current (WMC), Equatorial Jet (EJ), South Equatorial Current (SEC), South Equatorial Counter Current (SECC), and Indonesian Through Flow (ITF). The procedure adopted for estimating linear trends of the current systems uses a least square error-minimizing procedure. It is observed that among the nine major current systems, SC, EJ, WMC, and SECC are exhibiting decreasing trends with 0.12, 0.11, 0.16, and 0.18 cm/sec per year, whereas SEC and ITF show an increasing trend of 0.15 and 0.18 cm/sec per year, respectively. The trends of the other three major current systems, such as WICC, EICC and SMC are observed to be insignificant. These results will act as a benchmark to evaluate the performance of ocean model reanalysis products to mimic these observed trends in order to provide reliable ocean climate services.

Keywords: Geostrophy, Ekman, Buoyancy, SEC, ITF, SECC, WMC etc.

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Bias correction of historical and future projections from CMIP6 models for the Indian Ocean region
[ABS-08-0231]

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India's large coastal regions, with a population of around 170 million, are impacted by extreme climate events caused by global warming. Global climate models (GCMs) from Coupled Model Intercomparison Project-6 (CMIP6) have a coarse resolution, which makes it difficult to develop efficient adaptation and mitigation strategies under the climate change scenario. In such cases, dynamical downscaling using regional climate models (RCMs) is one of the best approach to obtain higher-resolution projections that are useful for the coastal regions. However, owing to the coarser resolution, the CMIP6 models yield relatively weak intraseasonal variabilities, which are significant for the internal variability of the ocean. Also, the mean of the CMIP6 atmospheric forcing fields may differ significantly from the mean of the forcing fields used to spin up the model. Hence, we observe a considerable bias in the CMIP6 fluxes, and consequently, the dynamically downscaled projections are impacted. To avoid this, performing a bias correction of the CMIP6 forcing fields for the Indian Ocean prior to dynamical downscaling is considered better. In the present work, atmospheric and oceanic variables from selected CMIP6 models are bias-corrected using the 3-hourly European Centre for Medium-Range Weather Forecasts Reanalysis 5 (ERA5) dataset and monthly SODA-3.3.1 dataset from 1980 to 2010, respectively, for the historical time period (1980-2014) and future projection scenario SSP5-8.5 (2015-2100). The bias adjustments are carried out based on a time-varying delta bias correction method. The biases present in the CMIP6 mean field are corrected using the mean from re-analysis data while retaining the inter-annual variability from CMIP6. The analysis demonstrates that bias-corrected surface atmospheric and boundary forcing fields with a climatological mean from re-analysis and a non-linear trend from CMIP6 are capturing variabilities better than the original CMIP6 data.

Keywords: projected atmospheric fields, high frequency variability

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Unleashing the mystery of super cyclonic storm Amphan's rapid intensification: An exploration of aerosol redistribution and devastating impact

[ABS-08-0485]

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The rapid intensification of tropical cyclones remains a puzzling phenomenon, and Super Cyclonic Storm Amphan (2020) over Bay of Bengal was no exception. This study delves into the mystery of Amphan's rapid intensification by investigating the role of aerosol redistribution and its devastating impact. By utilizing ERA5 re-analysis data and MODIS data of PM2.5, black carbon, sea salt and other aerosols, we shed light on the intricate relationship between aerosol distribution and cyclone intensification. The analysis reveals that during Amphan's intensification phase, there was a significant redistribution of aerosols in the storm's vicinity. The combination of anthropogenic and natural aerosols played a crucial role in modulating the storm's strength. The presence of these aerosols acted as cloud condensation nuclei, leading to the formation of numerous small cloud droplets and subsequent enhancement of the storm's convective activity. This, in turn, fuelled the intensification process, transforming Amphan into a super cyclonic storm. Furthermore, the study investigates the devastating impact of Amphan on coastal regions. The elevated concentration of aerosols, including fine particulate matter and black carbon, in the storm's core had far-reaching consequences. The high wind speeds and torrential rainfall associated with Amphan resulted in the transport of these aerosols inland, leading to severe air pollution episodes. The prolonged exposure to polluted air posed significant health risks for the affected population, exacerbating respiratory problems and other related ailments. The present study underscores the need for continued research into the complex interactions between aerosols, cyclones, and their devastating impacts, ultimately contributing to the resilience and safety of coastal communities.

Keywords: Tropical cyclones, MODIS data black carbon and PM2.5

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Spatio-temporal variability of Chlorophyll-a, Sea Surface Temperature and Sea Surface Winds and their inter-relationship along Northern and Northwestern Arabian Sea.

[ABS-08-0156]

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Spatio-temporal patterns of Chlorophyll-a (Chl-a), Sea Surface Temperature (SST) and Sea Surface winds using 8-day OC-CCI, MODIS, CCMP data, respectively, from 2003 to 2021 along coastal North and Northwestern Arabian Sea (AS) shows 2 blooms in a year - for Southwest Monsoon (SWM) and Northeast Monsoon (NEM), of which SWM blooms is more dominant in western region and NEM blooms are widespread during winters in Northern AS. The region when divided into 7 parts for detailed investigation shows that over the years. SST has increased throughout the 7 regions indicating warming of the Sea over the years associated with climate change with highest increase of 0.8oC in Northern Regions. Seasonally, SST shows 2 phases, alternating warming and cooling (due to upwelling and NEM) in a year except for northern regions which shows only 1 phase of Warming and Cooling (suggestive of weak/no upwelling zone during SWM). The Chl-a has decreased in all the regions, maximum in northern regions that show highest increase in SST. During SWM northern and central Oman shows stronger Chl-a blooms associated with upwelling. Correlation between Chl-a concentration and SST is negative for the regions off central and southern Oman and northern Yemen (strongest off northern Yemen, -0.55). Winds are bimodal blowing from NE and SW during NEM and SWM respectively in a year. Winds also shows 2 phases of high and low speed off central to southern Oman and northern Yemen, while a Single phase for northwestern Arabian sea. In Northwestern AS during NEM, a low speed anticyclonic circulation develops in the month of January, which further intensifies moves southwards till April and moves landwards in Yemen in the month of May. Cooler, low speed continental winds are observed during Chl-a blooms in the Northern AS during NEM, while high speed local winds forcings from Oman and

Yemen causes upwelling and the associated Chl-a Blooms during SWM. Winds speed has decreased in the northern Arabian Sea and off southern Oman while for off central Oman winds have increased. Correlation between Chl-a and Sea Surface winds is Positive for all regions with highest off central Oman (0.52).

Keywords: Chlorophyll-a (Chl-a), Sea Surface Temperature (SST), Sea Surface Winds, Upwelling, Correlation

Role of aerosols and freshwater on the distribution of net primary production over the Northern Indian Ocean

[ABS-08-0126]

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A rapid increase in atmospheric pollutants (aerosols) over the northern Indian Ocean was reported in the middle of the 1990s associated with growth in industrialization in South and Southeast Asia. On the other hand, the increase in temperatures due to global warming enhances the stratification and suppresses the vertical transport of the nutrients to the surface which results in a decrease in net primary production (NPP) over the ocean. The vertical suppression of the nutrient supply may partially be compensated by the increase in atmospheric aerosols and freshwater discharge from the major rivers. In order to test this hypothesis, we made an attempt to understand the long-term trends in NPP and anthropogenic aerosol optical depth (AAOD) between 2001 and 2020. The warming of the Ocean is not uniform in the northern Indian Ocean and it is significantly warmed at the south of 12oN compared to its north. At the western Bay of Bengal, insignificant warming trends are noticed during the fall, winter and spring seasons associated with significantly increasing trends in AAOD and insignificant trends in NPP. Despite warming, the weak trends in NPP in the north of 12°N were associated with higher AAOD levels and their rate of increase suggesting that the deposition of nutrients from the aerosols seems to be compensating for declining trends due to warming. The decline in NPP trends at the eastern Bay may be supported by both atmospheric deposition and an increase in river discharge as supported by a decrease in sea surface salinity. This study suggests that the enhanced atmospheric aerosols and river discharge played a significant role in the spatial distribution of the warming trends and NPP in the northern Indian Ocean. The impact of both river discharge (real-time) and atmospheric pollution influence are not part of the ocean biogeochemical models and must be included in order to obtain precise simulations and future changes due to climate change.

Keywords: Net primary Production, Anthropogenic aerosol optical depth, SST, Northern Indian Ocean, Climate change

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Spatio-temporal variation of authigenic Nd isotope (ƐNd) in the Eastern Arabian Sea: Implication to the deep-water mass and continental inputs

[ABS-08-0158]

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lobal Thermohaline Circulation (GTC) plays a vital role in transporting heat, storing and distributing nutrients and CO2, and ultimately modulating the global climate. The intensities of AABW and NADW have been modulating in the past over the Glacial-Interglacial (G-I) time scale in the Northern Indian Ocean. Two gravity cores, GC02 (10°N & 74°E) and GC10 (14°N & 72°E), were collected at a water depth of 2475 m and 2055 m, respectively, from the Eastern Arabian Sea (EAS), which archive a depositional history of the last 50 ka. A high-resolution authigenic ƐNd record has been extracted from the carbonate and Fe-Mn oxyhydroxide fractions. ƐNd records of EAS show large variability ranging from -10.8 to -6.6 (GC10) and from -8.6 to -14.5 (GC02) with more radiogenic values representing cold/dry climatic events (HS 1 to 4, LGM, YD) and less radiogenic values during warm/wet periods (B-A and ED), suggesting significant variation in water masses along with continental inputs. The less radiogenic ƐNd value of GC10 core during warm periods reflects more occupation of NADW in the deep EAS, and more radiogenic ƐNd during the cold climatic events reflects the more intrusion of AABW in the Arabian Sea. The overall ƐNd of the GC02 core shows a less radiogenic signature than the pure water mass signatures of AABW and NADW, and GC10 records could be due to the release of less radiogenic Nd from sediments interacting with the water. The impact of the lithogenic fraction on the authigenic Nd of EAS varies spatially as we move from south to North, i.e., from GC02 to GC10 core because of the basin structure. The area surrounded by the Laccadive ridge and the western coast of India is strongly affected by the lithogenic input, which gets reduced outside the Lacadive basin. The past seawater ƐNd signatures could be the combined effect of the Southern water masses and the lithogenic inputs majorly under the influence of monsoon intensity. The high-resolution ƐNd from EAS reflects the change in water masses and the continental inputs over the millennial time and shows a strong coupling between equator and high latitude climate.

Keywords: Eastern Arabian Sea, Deep-water mass, Neodymium Isotope, Paleo Ocean circulation, Continental flux

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Impact of environmental parameters on the variability of Phytoplankton community in Arabian Sea

[ABS-08-0206]

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SAC-ISRO

The present study focused on understanding long term changes in phytoplankton size class (PSC) over Arabian Sea (AS) using 12 years (2010 to 2021) monthly remote sensing reflectance (Rrs) data from MODIS. At first, Rrs spectra at each pixel were inverted to chlorophyll-a concentration (chl-a) using non-linear optimization, which was then used to estimate PSCs based on a three component model tuned for Arabian Sea (Ali et al., 2022). Furthermore, the role of wind speed, sea surface temperature (SST), sea surface height anomaly (SSHa) and mixed layer Depth (MLD) in governing the spatio-temporal changes in PSCs was evaluated. Seasonal climatology of PSCs reveal that larger phytoplankton (micro-) dominates the northern AS during winter (Dec to Feb) and pre-monsoon season (March to May) with more than 50% contribution to the total chlorophyll-a (chl-a). During monsoon season (June to Sept) micro-phytoplankton dominance is observed off the Oman coast due to strong upwelling caused by south-westerly winds. Strong increase in micro-phytoplankton contribution (> 80%) off Kerala coast during the monsoon season is also captured by the climatology map. The smaller phytoplankton (pico-) is found to dominate the central and southern AS during both pre-monsoon and post-monsoon season when the waters become oligotrophic. Monthly data of all the parameters were converted into common spatial resolution: 0.25x0.25 deg and pixel wise Pearson's correlation coefficient (r) were estimated between the PSCs and the environmental parameters (Wind speed, SST, SSHa and MLD). The study reveals the critical role of SST and MLD in modulating PSC concentration throughout the AS basin. The percentage composition of micro- and nano-phytoplankton are negatively correlated to SST with r ranging between -0.8 to -1.0 to in northern and north-western AS, while %-composition of pico-phytoplankton has a strong positive correlation with SST. Near

the upwelling regions of western AS, wind speed showed positive correlation with both micro- and nano-phytoplankton. MLD is observed to have a positive correlation with micro- and nano- phytoplankton in Gulf of Oman and central AS, whereas negative correlation with pico-phytoplankton. Overall, the study enhanced the knowledge about seasonality in PSC distribution in relation to environmental parameters over Arabian Sea.

Keywords: Arabian Sea, Phytoplankton size class, Environmental parameters long term changes, winter blooms, Environmental parameters, long term changes

Coral-associated bacteria and their role in protecting corals from UV induced oxidative stress

[ABS-08-0362]

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Coral reef ecosystems have immense influence on coastal protection, fisheries, tourism, and biotechnology sectors. The negative impacts of climate change and anthropogenic inputs on the existence of coral reef ecosystems is a topic of concern for both scientists and policy makers. The oxidative stress induced by ultraviolet (UV) radiations, elevated temperature, ocean acidification and pollution weaken the symbiotic interaction between corals and microbiome, evidenced as bleaching of corals. On the other side, some groups of microorganisms secreted reactive oxygen scavengers and UV-absorbing molecules, which can protect their host cells from oxidative stress. The present study investigated the abilities of coral associated bacteria to form biofilms and block UV light. 238 bacteria isolated from different corals (Acropora sp., Pocillopora sp., Porites sp., Echinopora sp. and Podabacea sp.) collected from Lakshadweep islands were studied. Majority (184) of the bacterial isolates were classified based on the similarities of 16S rRNA gene sequences into Psychrobacter sp., Halomonas sp., Kushneria sp., Staphylococcus sp., Bacillus sp., Brachybacterium sp., Citrobacter sp., and Salinicola sp. The UV absorption properties were predominant among 75 % of the Halomonas, followed by Citrobacter (63 %), Psychrobacter (59%), Staphylococcus (52 %) and Salinicola (50%). The biofilm properties were prevalent among 80 % of Kushneria, followed by Psychrobacter (60 %), Halomonas (56 %), Staphylococcus (52 %) and Salinicola (50 %). Some of the isolates belonging to Kushneria, Halomonas and Psychrobacter showed a combination of biofilm formation and UV protection. The present study suggests that these bacteria may play a vital role in maintaining the health of the corals along with assisting in the resilience of corals against environmental stressors including UV induced oxidative stress. The isolates having both biofilm and UV blocking properties could be a potential candidate for developing probiotics for protecting corals from diseases through microbiome engineering.

Keywords: coral reef, coral bleaching, oxidative stress, climate change, probiotics

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Climate change and increasing risk of water associated diseases

[ABS-08-0366]

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Assuring access to safe water and sanitation facilities are important to avoid the recurrence of water associated diseases. The distribution of water associated pathogens such as Vibrio sp. and Leptospira are increasing in relation with the climate change, and the former has been designated as the barometer of climate change. Microbial pollution of aquatic systems, which have high human interactions extending from washing and bathing to transportation, fishing, and tourism, can contribute significantly to the spikes in the outbreaks of water associated diseases. Vembanad lake, situated along the southwest coast of India, was monitored for one year (2018-2019) and indicator of microbial pollution, Escherichia coli, and Leptospira were prevalent in the lake irrespective of the seasonal changes in hydrographic variables. A surge in the incidence of acute diarrheal disease and leptospirosis were recorded during the 2018 south-west monsoon, when once-in-century floods affected the region. Remote sensing images showed that the inundation of the low-lying areas of Vembanad lake was extensive during the 2018 floods, which led to mixing of septic sewage with lake water. The incidence of disease was higher during June-October, during which the chances of humans encountering with contaminated water was much higher compared to dry season. The high abundance of Leptospira sp. in Vembanad lake presses the need of policies and practices for environmental hygiene, which can be achieved through proper waste management plans avoiding the leaching of pathogens to the lake. The combinations of lack of environmental hygiene and flash flood associated with climate change are dangerous combinations which can increase human interaction with contaminated water bodies and thus the chances of disease outbreaks.

Keywords: Leptospirosis, Escherichia coli, acute diarrhoeal diseases, flash flood, climate change,Vembanad lake

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Diversity of Symbiodiniaceae revealed thermal resilience and adaptation of coral reef in Palk Bay

[ABS-08-0425]

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Climate changes has led to increase in sea surface temperature where the relationship of coral and its algal symbionts undergoes distress leading to coral bleaching and mortality. According to latest research the symbionts associated with coral host interchanges based on the specific requirement like for thermal resilience and adaptation. At present there is a dearth in knowledge of Symbiodiniaceae associated with Indian corals. Palkbay is a major Indian coral reef subjected to annual bleaching events and anthropogenic pollution. Therefore, it is imperative to understand the diversity of Symbiodiniaceae in palkbay to predict future resilient patterns. Here, we use high-resolution analyses of next generation sequencing-based internal transcribed spacer 2 (ITS2) amplicons to investigate the diversity and structure of the Symbiodiniaceae communities associated with these marginal reefs. A total of 40 samples consisting of corals (Acropora digitifera, Acropora formosa, Favites abdita and Porites lutea) and reef environment (sediment and water) are considered for wider in-depth analysis of Symbiodiniaceae communities among them by implementing SymPortal analysis framework to predict intragenomic variants of Symbiodiniaceae. We Found that Palkbay corals are predominantly associated with Cladocopium (clade C) and Durusdinium (Clade D) which are generalist and thermal resilient symbiont species respectively. Symbiodinium (Clade A) was found only in few samples from sediment in agreement with previous studies it was found to be in benthic sediments. Within symbiont genera, the majority of ITS2 rDNA type profiles were unique to their respective coral host species, confirming the existence of host-specific symbiont lineages. The 14 ITS2 type profiles predicted from the samples comprised of 6 in Cladocopium, Durusdinium (6) and Symbiodinium (2). Further analysis revealed that the thermal resilient coral species ie. Favites abdita harbored the vast diversity (7) of type profiles of Symbiodiniaceae. The species of both Acropora and Favites have

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specific ITS2 intragenomic sequence variant D1/D2-D4-D4c-D1c and D1/D4/D2-D4c-D1c-D1h. Whereas Porites majorly clings to the variants from Cladocopium which is a definitive of cladocopium thermophlium group. Together, our findings indicate that co-evolution of host-Symbiodiniaceae partnerships favors fidelity rather than flexibility in marginal environments of India.

Keywords: Coral; Climate change; Symbiodiniaceae; Thermal resilience; Palkbay

Contrasting sea level trends in the Arabian Sea and the Bay of Bengal using satellite altimetry

[ABS-08-0037]

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Multidecadal sea level variations and the factors influencing the same in the North Indian Ocean and its sub-domains, the Arabian Sea and the Bay of Bengal, are analysed from 1993 to 2018 using satellite altimetry, ocean, and atmospheric numerical model datasets. In the Arabian Sea, sea level trends are negative from 1993 to 2003 (-1.3 mm/yr), positive from 2004 to 2014 (4.8 mm/yr), and higher from 2015 to 2020 (7.1 mm/yr). The Bay of Bengal Sea level trends remained positive from 1993 to 2003 (2.4 mm/yr), escalated from 2004 to 2014 (6.2 mm/yr), and dropped after 2015 till 2020 (-5.3 mm/yr). Steric sea level, prominently the thermosteric component, dominates total sea level anomalies, indicating thermal expansion as the main factor impacting sea level variations. Unlike the Bay of Bengal, halosteric sea level does not positively impact total sea level variability in the Arabian Sea. Ocean heat content and its rate of change in both basins agree with the sea level with a time lag, the latter being regulated by meridional heat transport across 9°N. Heat is lost from the Arabian Sea till 2001, beyond which it is retained, supporting sea level observations from thermal expansion. In the Bay of Bengal, positive heat transport anomalies show retention of heat from the beginning. Net surface heat fluxes play a minimum role in the total rate of change of heat content and are controlled by turbulent fluxes. Loss and retention of energy in both basins is further supported by increasing wind stress in both basins until 2000 and reduced variations thereafter. Basin stratification patterns explain the effect of wind stress and give grounds for further analysis of sea level variations in the Arabian Sea and the Bay of Bengal.

Keywords: sea level, heat content, Arabian Sea, Bay of Bengal, wind stress

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Estimating climate change associated coastal flood risk in Kochi, Kerala

[ABS-08-0086]

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Indian Institute of Technology Kharagpur

Projected increases in flood risk due to climate change, sea-level rise (SLR), and rapid coastal urbanization highlight the urgent need for effective management strategies to mitigate threats and minimize economic losses in coastal cities. It is crucial to develop accessible methodologies that can be utilized by non-experts and local planners to address flood risk at the local level. However, existing methods employed at regional and local scales often have limitations in comprehensively considering all components of coastal flood hazard, including storm surge and tide. Therefore, the primary objective of this study was to develop a user-friendly methodology for estimating coastal flood and inundation risk by leveraging the latest publicly available datasets, open-source software, and adaptable approaches. A passive modeling technique based on projected future water levels was employed to achieve this goal. The methodology was specifically applied to the coastal city of Kochi in Kerala, India. In addition to sea-level projections, tide and surge levels, as well as vertical land movements, were incorporated to model flood risk for the period 2023-2027. Vertical land movements, such as subsidence, can significantly increase the vulnerability of coastal areas to SLR but are often overlooked in inundation estimations due to the limited availability of GNSS measurements. To overcome this limitation, subsidence forecasts were generated using DInSAR timeseries data. Moreover, land use and land cover characteristics were considered to estimate the dampening effect on floodwater, thus reducing the risk of overestimation when using bathtub models. By integrating these various components and employing an accessible methodology, this study aims to provide a comprehensive framework for estimating coastal flood and inundation risk in coastal cities, facilitating informed decision-making and enhancing resilience in the face of future challenges

Keywords: Sea level rise, Climate change, Coastal Flood, Subsidence, Storm surge

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Heat Index rise over Goa, West coast of India

[ABS-08-0056]

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Goa University

Climate change is one of the biggest challenges of mankind. The rising global temperatures are increasing exposure to the heat, harms human health resulting in heat cramps, exhaustion, and life-threatening heat strokes. The foremost reaction of animals under thermal weather is increases in respiration rate, rectal temperature and heart rate. It directly affects feed intake thereby, reduces growth rate, milk yield, reproductive performance, and even death in extreme cases. The climate change exhibited as Heat Index, causes a negative impact on agriculture and the economy of the country. The hourly heat index from 1980-2022 was calculated at 12 locations over the state of Goa and the adjoining Arabian Sea using hourly dry bulb-temperature and dew pint temperature using ECMWF ERA 5 data. Results show that not only summers but even winters show a warming trend and rise in relative humidity. The computed heat index values were categorized into four classes viz. caution, extreme caution, danger and extreme danger as per National weather service, NOAA, USA. It was observed that the heat index over Goa and off Goa increases resulting in decrease in duration of caution category and increase in duration of extreme caution and danger categories clearly indicating a shift towards warming. The higher heat index mainly occurs in the months of April and May. Tourism being an important component of Goa's economy, the impact of rising heat index in the indoor/outdoor workplace is likely to affect the economy and hence is vital for formulation of policies for the efficient working environment, health and delineating the most favorable weather-period for tourism.

Keywords: climate change, dry bulb-temperature, dew point temperature, relative humidity, heat index, Goa

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A Review on marine plastic pollution

[ABS-08-0204]

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Marine Plastic Pollution is a major threat to marine ecosystem. The health of the marine environment is overwhelmed by the presence of marine plastic debris and it's unique properties for the past decades. The contamination of marine micro plastics is caused by the growing population, industrialization, urbanization , trade and other mining activities, which cause adverse effect on marine ecosystem. The presence of plastic pollution is not only affecting the global land but also the Oceans and Seas including Indian sub-continent. The China, one of the rapidly growing economies of the world, is the major contributor of plastic waste to the global environment (Mary H_Wang et al).The global plastic production has started since 1950s, the incredible productivity of polymers of this group increased year by year by four percent. Global plastic production was estimate at around 390.7million metric tons in 2021(Published by Statista Research Department, Mar 24, 2023). The ultimate objective of this paper is to review the all-available literature on Marine Plastic Pollution from as earlier year as available to 2023.

Keywords: Oceans and Seas, Marine Pllution, Plastic debris, Marine Ecosystem,Climate Change

Investigating the surge of extreme rainfall events in a coastal station Kochi: Unraveling the underlying causes

[ABS-08-0050]

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In recent years, the occurrence of intense rainfall events leading to flash floods has exhibited a notable rise in numerous regions across Kerala. An anomalous surge of heavy rainfall within a shorter duration was observed during the pre-monsoon season of 2022 at a coastal station in Kochi, Kerala. Analysis of station data revealed an exceptional precipitation of 817.9 mm from May 11th to May 26th 2022 within the study domain. The dynamics, thermodynamics and deep cloud properties play crucial roles in shaping extreme rainfall events. These alterations in precipitation patterns likely originate from deep convection, considering the tropical location of the study area. However, the precise physical mechanisms behind the escalating rainfall trends in this region remain unclear. Consequently, the primary objective of this research is to explore the relationship between cloud properties and the observed increase in rainfall. This investigation encompasses a comprehensive analysis of ground-based and satellite-based measurements, including rainfall, sea surface temperature (SST), wind velocity, sea-level pressure (SLP), ice water path (IWP), liquid water path (LWP), and other relevant cloud parameters. By scrutinizing these data, this study aims to unravel the influence of cloud properties on the intensification of rainfall within the specific study area. Notably, the findings indicate a strong association between days with high rainfall and the presence of deep convective clouds.

Keywords: precipitation patterns,Extreme rainfall, Deep convection

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Evaluation and projection of mean surface temperature variability over Arabian Sea using CMIP6 models

[ABS-08-0031]

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Sea surface temperature (SST) is a vital indicator of the Earth's climate system and plays a significant role in shaping weather patterns, ocean circulation, and marine ecosystems. The impacts of anthropogenic climate change on SST have been a subject of intense research. In this abstract, we examine the projections of sea surface temperature using data from the Coupled Model Intercomparison Project Phase 6 (CMIP6). The CMIP6 models provide valuable insights into future climate scenarios and enable us to understand the potential changes in SST due to climate change. The ability of Coupled Model Inter-comparison Project phase 6 (CMIP6) in simulating the seasonal and interannual sea surface temperature (SST) variability is evaluated over the Arabian Sea (AS). The historical simulations of 20 CMIP6 models are compared with the observations and standard reference data for evaluation purpose for 35 years (1980-2014). Statistical analysis reveals that all the models perform reasonably well over the Arabian Sea. The performance of CMIP6 models is determined by using four different model evaluation metrics as root mean square error (RMSE), standard deviation (SD), correlation coefficient (CC), and interannual variability score (IVS). The uncertainty in CMIP6 models will be observed by mean SST pattern over AS. Based on these parameters, the total rank of individual models is calculated for mean SST over AS to understand the performance of CMIP6 models. The projections of sea surface temperature using CMIP6 data indicate a consistent trend of increasing SST due to climate change. These projections have far-reaching implications for coral reefs, marine species distribution, extreme weather events, and coastal communities. Incorporating these projections into climate policy and planning

processes is crucial for developing strategies to mitigate and adapt to the impacts of rising SST and safeguard the health and resilience of the ocean in a changing climate.

Keywords: SST, CMIP6, Indian Summer Monsoon,Evaluation, Projection

A review on marine litter detection using remote sensing techniques

[ABS-08-0112]

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NCCR

The ecosystem as a whole is negatively impacted by the pollution brought on mainly by "Marine Litter", which refers to any refuse that has been inadvertently or purposely dumped into aquatic bodies. Traditional ship-based and manual surveys were done in an effort to ascertain the spatial distribution pattern of litters. Since remote sensing satellites have the capacity to cover enormous geographic areas and supply data for inaccessible locations and also aid in addressing the limits of conventional methods, researchers are drawn into it. This study reviewed the datasets and strategies utilised for detecting marine litter (including beach litter) using optical remote sensing. It is well-known that between the near-infrared and shortwave-infrared region, clear water shows strong absorption and floating matter shows reflection which helps to distinguish the water and litter pixels spectrally. Among the types of litters, plastics received special attention because of its prevalence and its negative environmental effects. Litter pixel detection using several existing indices (including plastic/litter indices) and band ratios were shown to be effective and the findings are positive. Recently, classification using machine learning algorithms with sufficient accuracy shows higher efficiency in separating water and sand pixels from litters. Due to better resolution with zero cost, the multispectral Sentinel-2 satellite sensor has been widely used for litter detection. Recently, aerial images from drone have also proven relevant for beach as well as marine litter detection studies. The accurate estimation of litters can be fulfilled by the use of UAVs since its not susceptible to weather conditions (e.g. cloud cover) and can be flown multiple times at lower altitude. Literature reviews showed that plastics had a peak reflectance in the near-infrared region, which serve as an important reference for developing algorithms using both multispectral and hyperspectral data. As a result, it is desirable to use remote sensing techniques to

detect marine litter since they can aid in management and decision-making. However, universally applicable and acceptable methods for litter detection need to be developed. More research on marine litter will be required in the future because there hasn't been enough done to properly comprehend how it affects society.

Keywords: Marine Litter, Remote Sensing, Sentinel, UAV

Amphibalanus reticulatus (Utinomi) demonstrates robust plasticity to acute temperature stress: Adaptive traits towards future climate change scenarios

[ABS-08-0260]

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The average mean global atmospheric level of CO2 is 417.2 ppm (2022) with an annual addition of 2.0 ppm. The IPCC (2014) has formulated the Representative Concentration Pathways [RCP] guidelines to reduce the levels upto the year 2081-2100. RCP 2.6 would result in a 1.0oC rise, RCP 4.5 in a 1.8oC increase, RCP 6.0 in a 2.2oC increase, and RCP 8.5 in a 3.7oC increase, with present emission levels in the RCP 8.5 range. Amphibalanus reticulatus has been found to be a prolific colonizer in the cooling water system of Madras Atomic Power Station outfall water boxes (OWB) and was found to grow upto 8-12 mm basal diameter. These OWB experience a ΔT 5 - 8oC consistently (24×7) than the ambient, has led us to investigate the effects of acute temperature on their survival, metamorphosis and settlement. Two laboratory assays were conducted; 1) acute exposures (20 min) of stage II nauplii to temperatures of 28, 34, 36, 38 & 40oC and monitoring their ability to complete the larval cycle, cyprid yield and attachment on substrates, and 2) Treating cyprids to acute exposure to temperatures of 28, 34, 36, 38 & 40oC and assessing their settlement. The nauplii survived (83%) and metamorphosed (95%) to complete their larval cycle despite acute exposures to varying temperature. Cyprid yield ranged from 70 - 77% at all temperatures. However, the settlement success of these larval forms was found to be impaired at 38°C and 40 oC. Acute temperature exposures had a profound effect on cyprids settlement and metamorphic behaviour. Percentage survival decreased with increase in temperature (97%) 28, (88%) 32, (71%) 34, (59%) 36, (31%) 38 & (9%) 40oC. Similarly, cyprid settlement was impaired with increase in temperature (51%) 28, (48%) 32, (47%) 34, (25%) 36, (4%) 38 & (0%) 40oC respectively. As per the current RCP in the forthcoming 77 years, our data shows that cyprid settlement and metamorphosis is not greatly affected with a ΔT of 4oC which is 32oC under the present climatic conditions. It is most likely that the barnacle settlement will not be threatened by future climate change scenarios.

Keywords: barnacle, temperature tolerance, cyprid settlement

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Buoyancy control of ARGO floats/ underwater gliders using Ocean vertical temperature gradient.

[ABS-09-0043]

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An environmental temperature variation of around 20◦C is abundantly observed along the Ocean depth environment (the Oceans surface temperature (25◦C) and that at 1000 meter depth (10◦C)). A suitable Phase Change material that can melt in the temperature range (of 15◦C to 25◦C) when exposed to this cyclic temperature variation undergoes volumetric expansion/contraction (10 to 12 %) can be used to generate hydraulic power, which can be used to control the buoyancy of ARGO floats/ underwater gliders, which are driven by varying their buoyancy. They have been in high demand recently due to their long endurance. This study proposes using the ocean vertical heat gradient as an energy source to improve the life cycle of float/underwater vehicles. It is widely known that there is a significant temperature differential of roughly 10 to 15◦C between the warm sea surface (25◦C) and the temperature at around 1000 meters depth. This temperature difference can be used to change the buoyancy of a float as it falls and ascends, utilizing Phase Change Materials (PCMs). Ocean thermal energy has not been thoroughly investigated owing to its low energy conversion efficiency. The theoretical limit of the Carnot cycle is only 6.5% for a temperature change between 1 and 20 ◦C. PCMs that can melt at a warm temperature of about 18 ◦C and solidify at a cooler temperature of about 10◦C and the ones that can exhibit a significant volume change of approximately 10-12 % in this temperature range have been studied.PCMs that can exhibit this behavior within the available temperature range during underwater floats/gliders travel in the ocean and can undergo maximum volume expansion are most desirable. Based on the vertical temperature profile of the Indian Seas, in our study, hexadecane has been selected. When subjected to ocean vertical temperature gradient, the PCM in the heat exchanger expands on melting or contracts on freezing. This expansion cycle can push the hydraulic fluid into an energy storage accumulator. The hydraulic fluid in the accumulator is pressurized with nitrogen to a pressure more than the ocean pressure.

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Keywords: Phase Change Material (PCM), Ocena Vertical Temperature Gradient (OVTG), Ocean Thermal Energy Conversion(OTEC),ARGO floats/ underwater gliders

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Advanced techniques for damage assessment of underwater structure

[ABS-09-0258]

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National Institute of Ocean Technology

Coastal structures like port and harbour play very pivotal role in strengthening the socio-economic growth of a nation. Hence, it is essential to design the structures as per the established industry standards and execute the plan accordingly. The poor estimation of design parameters (wave, tide, topography and bathymetry etc.) results in under design which leads to failure of the structure. Recently, a breakwater was damaged at the junction of trunk and head section due to overtopping of waves caused by underestimation of wave forces, inadequate crest level, and deviations from design during construction. In order to provide remedial measures for rehabilitation of the breakwater, a detailed analysis of the previous design and a damage assessment of the breakwater had to be carried out. Analysis of previous design can be carried out based on earlier studies. It is a challenge to assess the damage of the breakwater as significant part of it is underwater and in the breaker zone. In order to come up with an engineering solution, precise assessment of the damaged locations with slopes is required. To meet the project requirements, an innovative solution of combining aerial drone topography with 3-D underwater imaging was conceived. The section of the breakwater above the water level would be assessed with aerial topography and the underwater section with 3-D underwater imaging. After detailed analysis of the damage assessment, oceanographic observations, and vertical datum level, revised cross section of the breakwater was designed. This paper discusses the techniques applied for damage assessment of the breakwater.

Keywords: breakwater damage assessment, breakwater design, 3d underwater survey breakwater

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Illumination correction and restoration of blurred underwater images

[ABS-09-0471]

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Underwater images can be degraded by non-uniform illumination and blurriness caused by optical aberrations and unintentional motions due to imperfect imaging conditions. Degradation reduces the quality of the images. To restore the image quality from ill-posed to well-posed, the Illumination corrected Lucy (ICL) blind deconvolution framework is proposed for underwater image restoration. By establishing an image formation model based on the Jaffe-McGlamery underwater imaging model, a new cost function is developed that jointly achieves illumination correction and blind deconvolution. The latent image is not the final output of ICL, since it is oversmoothed. With the estimation of illumination pattern i and convolution kernel, a final non-blind deconvolution process is applied to the raw image. Initially the data are collected in many open water environments using underwater drone and gopro underwater camera. Then, these collected data are analysed based on Inherent Optical Properties and UIQM metrics. Finally, the degradations are restored using the proposed ICL method. ICL embeds the illumination correction in the framework of deconvolution, and efficiently avoids the problem where the kernel estimation may be degraded by problematic image intensity. The experimental results on underwater image blind deconvolution prove the efficiency and correctness of the L0-approximation strategy. In the non-blind deconvolution process, Lucy deconvolution method is adopted with the Hessian penalty to suppress the impact of noise signals and achieve deconvolution and illumination correction simultaneously. The ICL corrects the insufficient and uneven intensity distribution and increases the clarity of underwater images, benefiting the visual quality of underwater images from both objective and subjective aspects. The proposed ICL is compared against the state-of-the-art image blind deconvolution methods.

Keywords: blind deconvolution, deblurring, illumination, lucy, restoration, Underwater image

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Influence of warm core eddy on underwater acoustic propagation in the Bay of Bengal

[ABS-09-0189]

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The anomalous temperature and salinity structure associated with eddies causes sound speed variation in all directions, influencing long-range sound propagation. The present study aims to investigate acoustic propagation through a Warm Core Eddy (WCE) by means of a Parabolic Equation (PE) model. CTD observations in the northern BoB along 17 °N from 82.5 °E to 91 °E during winter (09-17 February 2016) onboard INS Sagardhwani with 0.25 ° station interval is utilised for the study. A WCE extending from 83.5 °E to 87.5 °E has been identified with its core at 86 °E. The eddy tracking is done using the software py-eddy-tracker with altimeter (CMEMS - sea level anomaly) data. The eddy was generated on 13th February and dissipated on 29th May 2016 (life span ~ 107 days). The thermohaline variability due to eddy is noted up to 300 meters vertically with a lateral dimension of 450 km. The convergence associated with the WCE leads to the deepening of Sonic Layer Depth (SLD) at the core. The SLD varies from 96 m to 29 m from the core of the eddy to its periphery. Transmission loss (TL) of 600 Hz is computed using the PE model along the observation track, with sound source at the core of the eddy at 25 m depth. The model is run for both range-dependent sound velocity data (using data from 17 stations across the eddy) and range-independent scenarios. Uniform ducted propagation along range is observed with range independent scenario, whereas non-uniform and shorter range of propagation is seen with range dependent case. Without eddy, the TL < 85 dB is observed uniformly in the duct up to a range > 250 km. Whereas, in the presence of eddy, towards the west, TL < 85 dB is observed at a range < 220 km upto 25 m depth and <120 km at 50 m depth. The detection scenarios predicted is having a very high influence of the eddy and hence will have relevance on SONAR design.

Keywords: Mesoscale eddies, acoustic propagation, parabolic equation model, underwater acoustics, transmission loss

Analysis of Various Controllers and Control Systems of a Remotely Operated Vehicle for Stabilized Navigation

[ABS-09-0009]

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A remotely operated vehicle (ROV) is an unmanned vehicle operated using a tether for navigation, control and underwater missions. ORCA is a low cost ROV which was indigenously developed for underwater inspection and survey. Due to unstable operating environments, dynamic modelling and simulation of the ROV is essential to understand the movements of the vehicle and accomplish stabilized navigation. ORCA has been mathematically modelled based on Newtonian dynamics in the Simulink platform to simulate the position and velocity responses of the vehicle. Different control system models were compared - open loop and closed loop systems (with controllers P, PI, PID). Open loop system was used to study the effect of various underwater forces on the vehicle. The closed loop system was developed to improve the navigation of the ROV in comparison with the open loop system. Finally, the closed loop system with a PID controller was found to be more suitable for stabilizing the ORCA ROV.

Keywords: ROV, Controller, PID, Open loop system, Closed loop system.

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Single point mooring load observation in Indian tsunami buoy system

[ABS-09-0295]

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The Indian Tsunami Early Warning System (ITEWS) is a collective effort of various organizations under the Ministry of Earth Science (MoES) working towards the aim of detecting, locating and determining the potential tsunamigenic zones in the Indian Ocean basin in order to prevent the sudden and unprecedented loss of life and damage to property in the Indian Ocean rim countries. The National Institute of Ocean Technology's Ocean Observation Systems (OOS) is a pioneer in maintaining moored buoy systems and has installed and maintained tsunami buoys effectively in the northern Indian Ocean. The design of the moored tsunami buoy system is equipped with the tension recorder to record and collect various in-situ loads induced by marine factors including wind, wave, and current while the buoy systems are exposed to various sea conditions. The tsunami buoy (ITB09) system with the underwater tension recorder was deployed on 15th February 2021 at a depth of 2360 m in the Bay of Bengal (17º07¿N and 90º00¿E) and retrieved on February 23, 2023. The buoy systems with the tension recorder had consistently worked over a long period of 729 days and collected nearly 822052 data sets. This paper depicts the field observed mooring tension data during different sea conditions. During normal conditions, the mooring experienced load of 800 kg (7.85 kN) acted upon the buoy systems and the mooring's maximum tension value at extreme conditions was recorded as 1140 kg (11.17 kN) during Nisarga cyclone in the Bay of Bengal with a very high wind speed of 100-110 km/hr recorded since the 1999 Odisha cyclone as per IMD reports. The field observed data was compared with the numerical analysis results. The numerical analysis was carried out using OrcaFlex software. The numerical analysis result for the Nisarga cyclone was compared with the measured tension recorder values and a very high correlation was found. The experimental and analysis data demonstrate that the NIOT moored buoy systems with mooring are well-designed and stable in the harsh marine environments and it gives real-time water level data for tsunami detection and warning for societal benefits.

Keywords: Tsunami buoy, Mooring Load, Mooring Analysis, Tension recorder,

Assessment of coastal protection structures at select locations along the Kerala coast

[ABS-09-0401]

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The Kerala coast, along the southwest of the Indian coast, has numerous mid-20th century rubble-mound-seawall structures erected to combat erosion. However, these structures face vulnerability to overtopping and potential damage due to rising sea levels resulting from climate change. Recent inspections have unveiled deterioration and altered profiles of these structures. A comprehensive study was conducted across nine susceptible locations spanning nine coastal districts along the Kerala coast to evaluate the present and future functionality of these structures under increasing sea level rise. Nearshore forcing parameters, including waves and water levels for 50 and 100-year return periods at a 10-meter water depth, were translated to the structure toe region to estimate damage, run-up, and overtopping for each structure. The assessment encompassed sea level rise projections based on the RCP-8.5 scenario, evaluating structure stability under modified forcing conditions. Multiple methods from existing literature were employed to assess seawall stability, with a 3% damage threshold as the acceptable limit. The study revealed heightened significant wave heights for the 50 and 100-year return periods. Surf similarity parameter values, referencing the CIRIA rock manual, indicated both plunging and spilling wave breakings along the Kerala coast. The run-up and damage values were projected to escalate under future climatic conditions compared to their present counterparts. Additionally, present crest freeboard (Rc) calculations, alongside overtopping estimations during monsoon and non-monsoon periods, indicated the structures' potential submergence in the future. This study provides crucial insights into the condition and performance of the mid-20th century rubble mound seawalls along the Kerala coast, emphasizing the urgency for adaptation measures to combat rising sea levels and changing wave dynamics.

Keywords: Seawall damage, Run-up, Crest freeboard, CIRIA rock manual, Overtopping rates

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Offshore porous wall wave fencing fish cage subjected to irregular waves: A Numerical study

[ABS-09-0225]

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The gradual global population increase leads to food supply chain demand. Fish is one of the significant proteins consumed by developing and poor countries, and offshore aquaculture has been booming rapidly in recent times. Optimum wave tranquility conditions must be present to obtain maximum production, and porous structures help better in wave energy dissipation. The present study considers a porous wall wave fencing fish cage with a porosity of 14.8%. The cage is positioned at 200m water depth with the help of non-linear catenary mooring lines. A set of irregular wave conditions is considered for a particular site location on the Karnataka coast. The significant wave heights (Hs) of 5-6m and peak periods of 10-13s are considered for simulation work. Hydrodynamic characteristics of motion responses and anchor line tensions are studied for different wave incident angles. Motion responses such as surge and pitch exhibited the highest peaks at wave incident angle of 0°, and as the incident angle increases, the motion responses decrease. The difference in heave motion for all wave incident angles are insignificant. Current and wind speeds of 0.25m/s and 6.12m/s are also considered, along with irregular wave conditions. The results indicate that the cage exhibits 2% -10% higher motion responses and anchor line tensions than wave-only conditions.

Keywords: Numerical Methods, Offshore Aquaculture, Porous Structures, Irregular waves

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A comparative study on wave dissipation by submerged composite porous breakwater and submerged composite pile-rock porous breakwater
[ABS-09-0432]

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A comparative study on wave transformation due to submerged composite breakwater and a submerged composite pile-rock breakwater is performed. The submerged composite porous breakwater consists of a submerged porous block and a vertical thin porous barrier whereas the submerged composite pile-rock breakwater consists of a submerged pile-rock porous block and a vertical thin porous barrier. The thickness of the vertical porous barrier is negligibly small comparted to the incident wavelengths. The linear wave theory is assumed and a mathematical method called eigenfunction-expansion technique along with mode-coupling method is adopted for the numerical analysis. The Darcy's law is incorporated for the flow through porous media and the porosity factor of the structure is introduced using the complex porous effect parameter. The wave reflection, transmission and wave energy dissipation are analysed numerically and a comparison on efficiency of two proposed composite breakwater systems is discussed. Various structural and wave parameters are considered in the analysis. The proposed comparative study gives an insight to wave energy attenuation by submerged composite porous breakwaters. The results on wave transformation due to submerged composite porous breakwaters can be helpful in design and implementation of coastal defense structures for coastal protection and achieving tranquility.

Keywords: Submerged composite porous breakwater system, pile-rock structure, submerged vertical porous barrier, wave dissipation, Eigenfunction-expansion method

Coastal sampler for automated plankton collection from desired depth: an important innovation for coastal ecology study

[ABS-09-0150]

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Environment plays a crucial role in maintaining the ecological diversity of living organisms. Thus, regular monitoring of the environment as well as regulating the pollutants is essential for maintaining the ecology of any given area. Planktons being the primary producers in aquatic ecosystem, monitoring of planktons would help in determining the overall health on any ecosystem. General method adopted for the plankton sampling was manually through a net and bucket, where a desired amount of water is filtered through the net with the help of a bucket. However, it was realized that manual plankton net-based sampling may not provide accurate results, because volume of samples collected through this net are not same as sometimes high-water currents result in unequal volume of water filtration through bucket on board in small boat. To counter the problem, a new plankton collection sampler called Automated plankton Sampler (APS) was developed. The device collects water from the sea using a on board pump having a controlled flow rate and passes it through two separate chambers fitted with different mesh size nets for filtration of phytoplankton and zooplankton separately. The filtrate is used for the analysis of selected physicochemical parameters of water. This makes it possible to use the device at any desired sampling location which can either be a boat or inland water. More specifically the device is used to collect water sample and plankton from sea water from varied depth levels. The device is easy to use and easy to clean, and therefore it can be ready for the subsequent sampling quickly as compared to the available manual method.

Keywords: Plankton sampler, Automated, Filtration, easy cleaning, depth specific sampling

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Optimising Design of Long Span Flood Gates for Coastal Reservoirs

[ABS-09-0224]

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Coastal reservoirs are gaining popularity these days as they can provide sustainable and reliable source of drinking water for coastal communities, particularly in regions where freshwater resources are limited. They not only provide fresh water but also prevent flooding during Storm Surge or Tsunami. They involve construction of dyke or bunds across the river or into the sea and store fresh water on the river side. The major challenge for these reservoirs is discharging flood water into the sea during extreme rainfall events, which is done using flood regulator. This operation becomes quite complex if the sea-side water levels during high tide are more than reservoir operating water levels. In this case, gates have to be closed during high tide and opened during low tide making operations complex (four times in a day in semi diurnal tide zones). The associated risk can be minimised by using a smaller number of long span gates. Conventionally, flood regulator gates are designed for a low span in rage of 15- 25m as it will be difficult to lift long span gates due to their massive weight. In this study three different configurations of vertical gates such as flat gate, flat gate with arch girders and lens shaped gate for 50m span are studied for flood regulator based on previously executed storm surge barriers. The gates are designed for storm surge event on the sea-side and maximum flood condition on the river side. A comparative study is carried out considering the quantity of material, ease of installation and operation. The study reveals that lens gates are ideal and optimum for long spans. However, if the gates have to be placed on control structures like ogee weirs due to hydraulic design, lens gate cannot be used due to non-availability of horizontal bottom and flat gates with arches need be considered.

Keywords: Long Span Flood Gates,Flat Gate,Arch Girder,Lens Shaped Gate,Coastal Reservoir

Tidal energy resource assessment along Andaman Islands

[ABS-09-0280]

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Tidal energy, known for its predictability and abundance, has gained global attention as a renewable energy source. With its extensive coastline spanning over 7,500 kilometers and numerous estuaries and tidal creeks, India holds significant potential for tidal energy extraction. The primary areas of tidal energy potential in India are concentrated in the Gulf of Kutch and the Gulf of Cambay in Gujarat. Additionally, the coastlines of West Bengal, and the Andaman and Nicobar Islands offer favorable conditions for tidal energy generation. An analysis was conducted to assess the tidal currents at different locations in the Andaman Islands, aiming to identify possible sites for tidal power plants. Hydrodynamic modeling studies were carried out using MIKE 21 software to predict various parameters such as current velocity, direction, and surface elevation. The study focused on Macpherson Strait, Homfray's Strait and Austen Straits, as these areas are open to the sea on both sides and experience significant tidal currents. In Macpherson Strait, the surface current velocity ranged from 0.1 to 1.55 m/s. Measurements of current velocities at various depths were obtained using ADCP by NIOT and were used to validate the model simulations. The analysis revealed that the current velocity varied from up to 1.2 m/s on the surface and increased with depth, reaching 2.2 m/s. Similarly, for Homfray's Strait and Austen Straits, analyses were conducted, and surface current velocities were found to vary up to 1.85 m/s and 1.48 m/s, respectively. These three sites show promising results, encouraging further comprehensive studies across the Andaman Islands. Overall, the study findings demonstrate the potential for tidal energy extraction in the Andaman Islands. The detailed analysis of tidal currents provides insights for identifying optimal locations for the installation of tidal power plants. This unique methodology can be adopted for the tidal energy resource assessment along other Indian coasts. These findings serve as a foundation for more rigorous studies, indicating a promising future for tidal energy development in this region.

Keywords: Tidal currents, Andaman islands, renewable energy, hydrodynamic modelling

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Finite Element Analysis for Micro Power Harvesting from Ocean Wave Energy using Piezoelectric Circular Diaphragm

[ABS-09-0372]

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Energy harvesting using micro power generators has become a major thrust area of research in terms of renewable energy during the recent decade. This research presents a piezoelectric micro power generator for harnessing energy from heave response of ocean floater buoys that can power up onboard sensors. A circular piezoelectric diaphragm is modelled and the output performance at low operating frequency is analysed using Finite Element Analysis (FEM). The different piezo materials such as PVDF, PZT-5H and AIN are selected for the model simulations. The sizes substrate and piezo material were varied by different diameters with regular circular shaped mesh elements to find the optimized sizes and the most suitable material for the harvester. The modelled piezo material has a different diameter of 25 mm, 30 mm and 35 mm and the substrate has a different diameter of 30 mm, 35 mm and 40 mm respectively with a thickness of 0.1 mm. The equivalent force and vibration which can be generated using the super ball during wave motion in ocean environment is configured as the forcing for the piezo diaphragm. Moreover, the vibration modes with respective frequencies from 50 Hz to 180Hz were analysed for the significant performance by varying the size of the substrate and the size of the piezo diaphragm. The maximum output voltage generated in between the frequency range 55Hz to 120Hz and the peak output voltage is around 2.81 V at 103.6 Hz. The finite element analysis simulation shows that the peak voltages is in-between 2.1 to 2.9 V for all the PVDF, PZT-5H and AIN materials. Also, the output of the piezoelectric energy harvester shows maximum trends of output power with the increasing resistive load unto the threshold level.

Keywords: Energy Harvesting, Finite Element Analysis, Piezo sensor, Circular Diaphragm

Estimation of Design Wave Height off Southeast Coast of India

[ABS-09-0473]

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The design of structures in coastal waters that are exposed to waves, currents, and tides necessitates the careful analysis of the spatiotemporal variability, particularly under the rapidly changing climate. The estimation of design wave height in shallow waters off Chennai is carried out using the ERA5 wave parameters during the year 1991-2020, which is validated using the Moored buoy measurements at 15m water depth during the year 2018. The wave measurements exhibit a moderate sea state in the study area with predominantly easterly and southerly waves. The wave height rarely exceeds 2.0m, with nearly 90% of the observations being less than 1.0m. Wave the period at the study area exhibits maximum occurrence between 5s and 8s, whereas that of the peak period more than 15s is observed during southwest monsoon season. The wave measurements exhibit the presence of swell waves throughout the year with higher occurrence during the southwest monsoon. The joint distribution of wave height and mean wave direction indicates higher occurrence in the southerly direction, where the maximum wave height is less than 2.5m. Stronger waves are observed in east- northeasterly direction with wave heights up to 4.0m. The waves in the south-southwesterly direction are comparatively calm, with wave height rarely exceeding 2.0m. The validation of ERA5 wave parameters exhibits good agreement with measured wave parameters and well captures the seasonal variability. The wave height is estimated using different methods. Among these, Generalised Extreme Value (GEV) appears to be the most appropriate. The significant wave height exhibits a correlation coefficient of 0.95, whereas the peaks during cyclones are overestimated. The maximum design wave height for the return period of 100 years is estimated as 6.10 m at 15m water depth in the study area. The estimation of design wave height using ERA5 design wave height needs to be carefully analyzed in view of the overestimation of the peaks in significant wave height, which may escalate the cost of construction due to an overdesign of the structure.

Keywords: Design wave height, Bay of Bengal, Moored data Buoy, ERA Wave,

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Wave transmission analysis of floating fish cage under regular wave excitations

[ABS-09-0220]

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In consequence of the global food demand spike, aquaculture production dominates the capture production at most of the places, since it's an exponentially growing industry and there are few constraints to maximizing the production. The water quality is the primary concern and better water exchange leads to better oxygen supplements for the fish, which further improves production. In order to study the water exchange in a cage, wave transmission studies are required. The present study considered the 1:75 scaled offshore square fish cage model with a net solidity of 0.24, and the cage is placed at 50-55cm water depths. A set of regular wave conditions are considered, such as wave heights ranging from 4 -14cm with an interval of 2cm and wave periods ranging from 1-2.2s with an interval of 0.2s. A series of experimental studies have been carried out on the cage in a 2D regular wave flume. The cage with net solidity of 0.24 exhibits a wave transmission coefficient (Kt) in the range of 0-8-0.7, which indicates good water exchange inside the cage.

Keywords: Experimental studies, offshore fish farming, scaled models, wave transmission.

Estimation of Polymetallic Manganese Nodules abundance in the selected area in Central Indian Ocean Basin (CIOB)

[ABS-09-0107]

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Polymetallic Manganese Nodules are mineral resources mostly found on the ocean's abyssal plains. They are mineral concretions mainly composed of manganese and iron bearing oxides, as well as minerals such as Ni,Cu,Co,Mo,Zr,Li, and rare earth elements. These minerals precipitate concentrically around a nucleus, either from seawater(hydrogenesis) or from sediment-pore water(diagenesis). The Central Indian-Ocean basin has the second-largest abundance of nodules after Clarion-Clipperton region in Pacific Ocean and has attracted attention due to its potential as a future source of strategic metals. NIOT, under MoES, Government of India, has realized a 6000m depth-rated Autonomous Underwater Vehicle named as Ocean Mineral Explorer(OMe-6000) from M/s Kongsberg Maritime, Norway. AUV was deployed in the location of 13°34.451N and 75°31.401E, at a water depth of 5270m in CIOB, to understand the high-resolution seabed signatures. The AUV is equipped with high-definition underwater camera, which captures images with a frame dimension of 6m×3m from an altitude of 5m. Surface features of the seabed observed in the underwater images from AUV, is used to quantify the abundance of nodules in CIOB. Two software programs were used for image processing and nodule quantification viz Ilastik and Cell-Profiler. Ilastik is a software that uses machine-learning based image analysis for interactive image-classification, segmentation, and analysis. It has various workflows in which the pixel-classification workflow is used to segment nodules and seabed. After training the classifier, it is applied to unseen images as batch-processing. Segmented images are obtained in which nodules appear as white dots against a dark background. The processed images are then fed into the Cell-Profiler, which counts the number of nodules, determines radius and percentage area covered by the objects. Nodule abundance is calculated assuming each nodule as a

spherical entity. Considering an average dry density of 2000kg/m³, the maximum abundance obtained is 6.9kg/m² at the deployed site with a close grid observation of 1km x0.5km. The highest abundance of nodules is observed in the southwest part of the study area, with a maximum of 187 nodules per square-meter. The northwest region of the study area also showed higher abundance but relatively less than that observed in the southwest region.

Keywords: Polymetallic nodules, Autonomous underwater vehicle, Deep sea mineral resources, Image processing, Central Indian Ocean Basin, Nodule abundance

A GPS-GPRS tracked surface drifter for monitoring estuarine surface currents

[ABS-09-0174]

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The Vembanad Lake, India's largest estuarine system is influenced by monsoonal changes and coastal dynamics. Examining estuary surface currents during tidal phase changes is beneficial, but altimeters face data reception issues near shorelines. A cost-effective surface drifter based on a Lagrangian technique has been developed to study the circulation and tidal currents in the Vembanad estuarine system. This drifter is equipped with GPS (Global Positioning System) module, GPRS (General Packet Radio Service) module and other electronic components that allow its real time tracking and helps to study the current patterns within the estuarine region by analysing the GPS location data of drifter recorded at regular intervals. A comparison of the current flow patterns derived from the designed surface drifter and an in-situ current meter was conducted and shows a good match between the two measurements.

Keywords: Surface drifter; Estuarine Circulation; GPS; GIS; Remote Sensing

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Laboratory and Field Based Evaluation of Marine Antifouling Property of 2(5H)-Furanone PDMS Composites

[ABS-09-0268]

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Halogenated furanones are potent quorum sensing inhibitor which act on the signalling molecules (such as N-acyl homoserine lactones) of marine microbes and reduce the bacterial mobility and inhibit biofilm formation. They have been demonstrated to inhibit attachment of bacterial species which serve as a source of cues for invertebrate larval settlement thus indirectly controlling macrofouling of surfaces. In the present study, 2(5H)-Furanone was loaded into the polydimethylsiloxane [PDMS] polymer [0.5% w/v] and used for attachment assays in laboratory using the marine bacterium S. lentus, marine diatom Amphora sp. and the seaweed Chaetomorpha linum. The Furanone-PDMS (FP) composites were also tested under field conditions in coastal waters for biofilm inhibition and macrofouling species settlement and succession. Laboratory studies showed 57% inhibition of attachment and biofilm formation of the bacterium S. lentus. A 2.1 times increase in levels of Reactive Oxygen Species (ROS) generation in bacteria was observed on FP composites compared to plain PDMS. A 15% decrease in settlement of the pennate diatom Amphora sp. was observed on the FP composite surface compared to plain PDMS. In-situ exposure in coastal waters revealed a 60% reduction of total viable bacterial counts in 7-day old biofilms compared to plain PDMS. FP composite failed to inhibit diatom colonization under field conditions. A 1.0% increase in diatom density in biofilms under field conditions was observed on FP composites compared to plain PDMS. Similarly, an increase of 1.1 times in total suspended solids content in biofilms was observed under field conditions. Reduced protein (0.201%) and carbohydrate (55%) levels was observed on FP composite compared to plain PDMS. The FP composite were able to resist settlement of invertebrate larvae upto 30 days showing a 73% reduction in total surface area coverage compared to plain PDMS. The FP composites offered excellent bacterial inhibition both in lab and field conditions,

whereas they were less effective in preventing invertebrate larval settlement in field conditions. FP composites offered broad spectrum antifouling activity and also serves as a natural product biocide which can be incorporated to combat microfouling on PDMS foul release surfaces.

Keywords: 2(5H)-Furanone,diatom attachment,bacterial attachment,antifouling

On the application of a fast robust search algorithm for extracting similar weather patterns in buoy data over the Bay of Bengal

[ABS-09-0418]

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Incois

In recent years, machine learning algorithms are and climate data. The focus of this article is on the time series data obtained over the Bay of Bengal. Over the Bay of Bengal, the most observed are the changing seasons and the intra-seasonal variability. Nevertheless, however, the variability is present across multiple time and spatial scales spanning minutes to years. It is hypothesized that the underlying variability may to some degree be analysed in terms of recurring patterns which can in turn provide insights to functional relationships for process based studies on air-sea interaction. Using a recently proposed algorithm on pattern discovery named the Subsequence Time Series Matrix Profile algorithm, nearly similar pattern search is carried out into the history of the time series variable. The algorithm extracts time series that are similar. The similarity in the subsequences is measured by computing the Eucledian distances across the time series. A matrix profile is constructed for the winds, temperature, salinity, ocean currents or for any variable of study. The search complexity is O(n^2). The subsequences search algorithm has been implemented for search related to fast changing ocean conditions like sudden drop/rise in air pressure, temperature, salinity, changing winds/ocean currents. This pattern search algorithm also significantly reduces the subjective uncertainties arising from manual search especially in long time series of climate data

Keywords: Search machine learning, pattern discovery time series

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Marine Geology and Geophysics

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Stress distribution in the Sumatra-Andaman region before and after 2004 mega thrust earthquake

[ABS-10-0101]

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The 26th December 2004 Sumatra-Andaman mega thrust earthquake (Mw 9.1) caused significant alterations to the in-situ stress. Specifically, the co-seismic stress rotation of the pressure axis, also known as the σ1 axis, led to an increase in the number of seismic events in different segments of the Sumatra and Andaman region. These changes may have long-term implications for the seismic hazard in the region. We try to understand the stress orientation of different segments of the Sumatra and Andaman region using iterative stress inversion of focal mechanisms solutions compiled from Global Centroid Moment Tensor (CMT) catalog and International Seismological Centre (ISC) bulletin from 1976 to 2023. To infer the stress rotation caused by 2004 Sumatra-Andaman earthquake, the stress inversion was performed prior and after major earthquake. The normal faulting has been activated extensively in the Andaman sea and the region east of the Nicobar Islands after the 2004 earthquake. We observed significant changes in the maximum principle stress orientation before and after the 2004 event, along the segments containing the Andaman Islands, Andaman back-arc spreading center and Sumatra coast.

Keywords: Sumatra-Andaman region, Normal faulting, Stress inversion, Maximum principle stress orientation

Low-temperature hydrothermal minerals studied from cratered seamount off Nicobar Island, Andaman Sea

[ABS-10-0138]

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The Andaman basin characterized by trench-arc-backarc elements is a complex active basin and is known for hydrothermal activity in some of the seamounts (subaerial and submarine) of the volcanic arc. In the present study, 13 submarine seamounts (SM1-SM13) in the southern Andaman volcanic arc, extending from 6o47¿N: 94o43¿E to 7o 56¿ N: 94o 2.47¿E, were surveyed onboard RV Sindhu Sadhana (November 2021) to understand the hydrothermal activity. At one of the crater seamounts (SM-13) we have observed evidence for hydrothermal activity characterized by gas flares in the water column, live chemosynthetic organisms (Bathymodiolus species), and low-temperature minerals such as barite, colloform silica & orpiment. The occurrence of low-temperature hydrothermal minerals such as tabular barite, colloform silica, and orpiment from the rock samples indicates that the hydrothermal activity is at its initial stage. Earlier studies (Raju et al., 2012; Prakash et al., 2012) carried out in 2007 did not observe any gas seepage or live organisms other than ferromanganese oxides of low-temperature hydrothermal type. The present study infers the development of a new hydrothermal vent field in the Andaman volcanic arc.

Keywords: Hydrothermal Activity, Andaman Basin, Low Temperature Minerals, Orpiment, Silica

Characterizing the distinctive signatures of fluvial, biogenic, and diagenetic magnetic minerals in late quaternary sediments from the Southwestern Bay of Bengal

[ABS-10-0105]

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The signatures of magnetic minerals originated from differing sources, and their relative magnetic contribution to the continental margin sediments is crucial in understanding sediment transport, paleoenvironmental changes, and provenance variations. In the present study, we employed the magnetic end member unmixing technique to isothermal remanent magnetization (IRM) curves of Late Quaternary sediments from the southwestern Bay of Bengal. IRM decomposition of individual end members revealed source-specific magnetic mineralogy. The magnetic properties of the two end members indicated fluvial signatures of different river systems. Changes in the magnetic remanence contribution in the studied sediment core can be linked to variations in the Indian monsoon and source rock chemical/physical weathering. Alternating field demagnetization experiments, magnetic parameters, and transmission electron microscopy results point to the significant presence of biogenic magnetite. The magnetic remanence contribution of biogenic magnetite was up to 80% during the deglaciation period highlighting their importance as a substantial remanence carrier in continental margin sediments. The emergence of magnetic end member characterized by coarse antiferromagnetic mineralogy indicates high titanium magnetic mineral phases that survived the reductive diagenetic processes. Our study effectively identified and differentiated the magnetic mineral signatures of fluvial, biogenic, and diagenetic origin in sediments from the continental margin. We also highlight the significance of evaluating the presence of biogenic magnetic minerals, often neglected in marine sediments, to ensure precise interpretation of the standard rock magnetic proxies.

Keywords: Magnetic Minerals, Late Quaternary, Southwestern Bay Of Bengal, End Member, Biogenic Magnetite

An enigmatic geochemical signature for metal-driven anaerobic oxidation of Methane in a sulfidic coastal hypoxic sediment of Eastern Arabian Sea

[ABS-10-0129]

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Anerobic oxidation of methane (AOM) is an important biogeochemical process in anoxic marine sediments responsible for consumption of methane. Although AOM coupled with sulfate reduction is considered to be common in anoxic marine sediments, evidence for metal oxide-driven AOM is relatively insufficient. Here we report geochemical evidence for metal-driven AOM in a sediment core collected off Goa (SSD070/GC6) within the coastal hypoxic zone of the Eastern Arabian Sea. The porewater methane concentration profile shows repeated depletion in concentrations coupled with enhanced Fe2+ and Mn2+ concentrations. The high concentration of porewater Fe2+ and Mn2+ at depths corresponding to low methane concentration indicates the possibility of AOM process mediated by the reduction of mineral-bound Fe (III) and Mn (IV) (represented by Eq. 1 and 2) (Beal et al., 2009) since pore-water sulfate is almost exhausted at around 287 cmbsf (< 0.4 μM). CH4 + 8 Fe(OH)3 + 15H+ → HCO3- + 8 Fe2+ + 21H2O (Eq.1) CH4 + 4 MnO2 + 7H+ → HCO3- + 4 Mn2+ + 5H2O (Eq.2) Previous studies suggested that the absence of sulfides allows Fe2+ to accumulate at high concentrations. In contrast, porewater sulfide concentration was high throughout the core, varying from 3.3 to 10.38 mM. A buildup of porewater ferrous Fe at depth in the presence of high hydrogen sulfide concentration could indicate ongoing Fe reduction in the CH4 - bearing coastal hypoxic sediments pointing to a potential coupling between Fe oxide reduction and AOM. Here, we observed for the first time, depleted residual methane isotope ratio coupled to metal-AOM process, which was earlier found to occur during SO4-AOM. Paradoxically, the depleted carbon isotope ratio of methane observed at potential Fe-AOM sediment layers may be due to the back flux of DIC to CH4 during AOM (Yoshinaga et al., 2014). In addition, the porewater geochemical data also show an increase in Mo concentration which might

have been released during the reductive dissolution of the Fe/Mn-(oxyhydr)oxides. Our study demonstrates that metal-driven AOM is an additional methane oxidation pathway in iron/manganese oxide-rich sulfidic coastal sediments with low to undetectable sulfate concentrations.

Keywords: Anaerobic Oxidation Of Methane, Metal Driven- AOM, Iron/Manganeese - (Oxyhydr)Oxides, Depleted Carbon Isotope Ratio, Coastal Hypoxic Sediment.

Geochemical reconstruction of tubular high Magnesian Carbonates and Aragonite crusts from a Methane seep site of the Krishna-Godavari basin

[ABS-10-0143]

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Active and relict methane seep sites are extensively reported from marine sediments. Methane seepages are characterized not only by a unique ecosystem consisting of chemosynthetic organisms and a variety of heterotrophs including molluscs and crustaceans, but also by carbonate mounds and crusts. The precipitation of carbonate minerals within the sediments is attributed to anaerobic oxidation of CH4 (AOM) coupled with reduction of dissolved SO42- which leads to enhanced porewater carbonate alkalinity. This microbially mediated reaction is carried out by a consortium of methane oxidizing archaea and sulfate reducing bacteria at the sulfate methane transition zone (SMTZ). In the present study we have used carbonate morphology, petrographic and geochemical characters to highlight the distinct precipitation conditions of tubular high-magnesian calcite (HMC-tubes) and aragonite-crusts (arg-crust) recovered from the methane seep sediments sites off Krishna-Godavai Basin, Bay of Bengal. The tubular carbonate is the dominant morphological type. The tubes are often partially to wholly filled with micritic carbonate. The tubes range in length from ~1 cm to 21.5 cm, having a diameter ranging from ~0.3 to 2.3 cm. The tubes are composed of HMC, whereas the gas conduits /cavities are lined with botryoidal/ acicular aragonite Aragonitic carbonate crusts recovered at the study site are cavernous with botryoidal aragonite lining the cavity walls. The crust is mixed with chemosynthetic shell fragments and microcrystalline aragonite cement with minor low Mg calcite. Carbon (δ13C) and oxygen (δελτα 18 O) isotope ratios of HMC-tubes range from -54.5 to -46.2 and 4.3 to 6.2¿ respectively, whereas delta13C and delta18O isotope ratios of arg-crusts range from -57.6 to -34.8 and 1.8 to 4.3 ¿ respectively. The HMC-tubes and arg-crusts show distinct PAAS-normalized REE distribution patterns. The PAAS normalized MREE and HREE values are distinctly higher than the LREE

values in HMC-tubess, whereas, PAAS normalized LREE values are higher than that of MREE and HREE values measured in the arg-crusts. The total LREE/total HREE ratios vary from 6.3 to 18.2 in HMC-tubes and 25.21 to 143.67 in Arg-crusts. The studies show the two carbonate types form at distinctly different geochemical conditions close to the sea bed.

Keywords: HMC, Aragonite, Tubular Carbonate, Methane Seepage, Krishna-Godavari Basin

Morphological characteristics of deep-sea sinuous channel-levee system of upper Indus fan: New insights from high-resolution marine geophysical data

[ABS-10-0169]

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The Indus fan, the world's second-largest submarine fan deposit, is a significant physiographic feature in the Arabian Sea, spanning an area of approximately 1.1 million km2. These channelized fan systems are of growing research interest due to their role in sediment, organic carbon, nutrient, and contaminant transfer to the deep sea, as well as the creation of substantial hydrocarbon reservoirs. Previous studies have documented the presence of deep-sea sinuous channel systems on the fan. However, the upper Indus fan's channels remain incompletely mapped, primarily due to a lack of high-resolution bathymetry and seismic reflection profiles. In this study, we used high-resolution multi-beam bathymetry data acquired by the National Centre for Polar and Ocean Research, Goa as part of the Exclusive Economic Zone mapping program to study the geomorphologic and morphometric characteristics of the deep-sea sinuous channel-levee system of the upper Indus fan. The data reveals the presence of highly meandered deep-sea channel-levee systems with distinct erosive-depositional features like stepped terraces, levees, and steep flanks. Morphometric analysis of the identified channels was carried out to determine the parameters such as bank full width, gradually varying curvature, and sinuosity. The sinuosity of the channels in the upper Indus fan is found to be varying between two to three, indicating high sinuosity of the channel. Further to understand the internal architecture and channel migrations, multi-channel seismic reflection (MCS) sections across the Indus channel were analyzed. Seismic data reveals two well-developed buried channels of the Indus fan, indicating channel migration in the past. The detailed analysis of the newly acquired multibeam bathymetry complimented with the MCS data will enhance the understanding of the morphology, internal architecture and evolution of the Indus Fan channel-levee systems.

Keywords: Submarine Fans, Indus Channel, Channel-Levee System, Geomorphology, Arabian Sea

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Seafloor spreading in Western Indian Ocean: Interactions between Carlsberg - Central Indian Ridges and Off-Ridge thermal sources

[ABS-10-0498]

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Seafloor spreading along the Carlsberg and Central Indian Ridges (CR and CIR respectively), spanning between the Owen Fracture Zone (OWZ) in the north and Rodriguez Triple Junction (RTJ) in the south, steered the tectonic evolution of the western Indian Ocean. Notable variations in spreading rate, segmentation, and morphology of the CR and the northern and southern parts of the CIR (NCIR and SCIR respectively) are noticed. Furthermore, the proximity of Reunion hotspot and the Indo-Australian Diffuse Boundary Zone, appears to influence the crustal accretion and subsidence characteristics along these ridges. Despite numerous previous geophysical investigations, CR and CIR remain a comparatively less studied part of the mid-oceanic ridge system of the Indian Ocean. This study employs satellite-derived geoid and gravity anomaly measurements to examine the variations in the isostatic state, crustal accretion, and ocean floor subsidence along these ridges. The analysis focusses on determining deviations from the expected gradual progression of the spreading centre as a linear structure between the OWZ and RTJ under the influence of the proximal thermal/magnetic sources. To decipher these deviations, we calculate and analyse the Effective Elastic Thickness (Te), Geoid-Topography Ratio (GTR), Residual Depth Anomalies (RDA), and residual geoid-age slopes along these ridge systems. Significant variations in the Te and GTR are observed along the CR and CIR, indicating changes in the lithospheric strength and isostatic equilibrium. In particular, the NCIR segments where the proposed Diffuse Boundary Zone intersects with the ridge system yields lower Te values (11-13 km) and higher GTR (in degree-50) values (0.87-0.93 m/km) compared to those of CR and SCIR (Te = 15-17 km & GTR = 0.61-0.69 m/km). Additionally, intriguing asymmetries, statistically quantified by 'asymmetry factors', are observed in the degree-10 residual geoid and RDA patterns along the entire ridge system. Along the southern flank of CR, distinct changes in

geoid-age slope are observed between crustal ages of ~20 Ma (northernmost segment) and ~5 Ma (southernmost segment). Contrasting bipolar asymmetric factors in geoid and RDA for the NCIR (2-4) and CR and SCIR (upto ~-2.2) suggests distinct segmentation among the ridge systems. The highest negative asymmetry values (~-2.2) are observed in the SCIR segments closer to the present-day Reunion hotspot. Although seafloor spreading at mid-oceanic ridges is ideally regarded as a symmetric mantle process beneath young ocean floors, the presence of proximal thermal sources can exert considerable influence on mantle convection, melt generation, subsidence, and internal deformation. The unusual changes in geoid slopes of the CR segments are interpreted as a consequence of the interaction with the Owen Transform Fault which was initiated approximately 20 million years ago at the tip of the CR. The flatter geoid and RDA variations on the eastern flanks of the NCIR segments and the unusual lithospheric weakening at this location confirm the interaction of the ridge with the anomalously hotter lithosphere of the Diffuse Boundary Zone. Along the SCIR, a previously proposed flow connection from the neighbouring off-axis hotspot is evidenced in the flipped geoid and RDA asymmetry. Overall, the results suggest that, despite the gradual increase in spreading rates of CR and CIR between OWZ and RTJ, the isostatic state, melt generation and subsidence do not follow a continuous progression along CR and CIR. Instead, the presence of proximal thermal sources exerts predominant influence at specific regions of the ridges and resulted in terms of distinct segmentation patternsand differential subsidence. 1) An inspiring and engaging ocean We exist because oceans exist. But why do oceans exist is still unknown to most of us. The Earth has a radius of approximately 6,371 km. It is fascinating to note that the crust, which is the upp

Keywords: Western Indian Ocean, Mid Oceanic Ridges, Diffuse Boundary Zone, Reunion Hotspot, Geoid, Gravity

Does the nature of subducting Lithosphere influence stresses and rupture propagation along Andaman Sumatra Java Subduction Zone?

[ABS-10-0312]

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The distribution of the normal fault earthquakes along the Andaman Sumatra Java Subduction Zone (ASJSZ) is used to investigate the origin and cause of the stress distribution along the subduction zone. The normal fault hypocentres ranging from 10 to 80 km depth, originated in post-2004 megathrust, have been categorized to six clusters. Each of the clusters has been projected on different slab models interpreted from seismic sections traversing ASJSZ, indicating the importance of normal seismicity in the oceanic mantle between ~20 and ~40 km depth. The influence of the late Oligocene internal deformation in the reactivated fracture zones of the Wharton Basin is manifested as left-lateral strike-slip faults. This resulted in right lateral shearing of the lithosphere within the fracture zone compartments through sets of en-echelon normal faults, oblique to the spreading fabric, and parallel to the direction of the principal compressional stress. However, the WNW-ESE strikes of four normal fault earthquake clusters are consistent with the trend of en-echelon normal faults observed on the bathymetry west of the Investigator Fracture Zone. Furthermore, the background seismicity distribution through time and the rupture zone extension along the ASJSZ is compared with the various spreading rates and fracture zones observed on the downgoing plate, with the expectation that the different crustal roughness and lithology characteristic of a lithosphere formed at slow, intermediate or fast spreading rate may explain the observed patterns of the rupture propagation. While the fast-spreading lithosphere promoted the propagation of the 2004 megathrust rupture zone, there is no direct correlation between the rupture zones and the spreading rate. Two fracture zones only impeded the rupture propagation of the 2004, 2005, and 2007 megathrust events, possibly because slab tearing is affecting these subducted fracture zones.

Keywords: Andaman-Sumatra-Java Subduction Zone, Normal Fault Earthquakes, Apparent Stress, Rupture Propagation, Spreading Rate, Fracture Zone

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Source characteristics of small magnitude earthquakes (M<5) in the Andaman-Nicobar Islands

[ABS-10-0261]

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We analysed the P- and S-waveforms for 74 local earthquakes (M<5) occurred in the Andaman-Nicobar Islands to characterize the earthquake's source. Brune's spectral model is used to calculate the source parameters such as seismic moment, corner frequency, moment magnitude, stress drop, source radius from both P- and S-waveforms. The fast fourier transformation of the seismic waveforms was carried out to calculate the displacement spectra of P- and S-waves. Andrew's approach is applied to obtain the corner frequency for the P- and S-waves. The long period spectral level and quality factor were calculated while applying a grid search approach on the displacement spectra. We assume uniform velocity of P and S waves and a circular fault at hypocentral depth of the events to calculate the Brune's stress drop based on the estimate of seismic moment and corner frequency. Further, the scaling relations among the various source parameters has been obtained to characterize the small magnitude earthquakes in the region. A breakdown in the scaling relation has been noticed for the small magnitude earthquakes in the region. The earthquake source parameters, such as seismic moment, source dimension, Brune stress drop, and corner frequency etc., and scaling laws among source parameters are important for understanding the tectonics governing the earthquake genesis and are useful for the prediction of ground motion, aftershocks pattern, and seismic hazard assessment. The stress drop is one of the key source parameter which measures the change in average state of stress on fault before and after an earthquake. The scaling relation between Brune stress drop and seismic moment shows the decrease in stress drop with a decrease in the seismic moment. The low Brune stress drop indicates anomalous behaviour of small earthquakes in the region. The stress drop and seismic moment are two important parameters to characterise the source zone, the property of the medium, and prediction of risk vulnerability for potential future earthquakes. Stress drop and seismic moment shows the decrease in stress drop with a decrease in the seismic moment. The low Brune stress drop indicates anomalous behaviour of small magnitude earthquakes in the Andaman Nicobar region

Keywords: Stress Drop, Seismic Moment, Corner Frequency, Moment Magnitude,

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Deep lithospheric structure beneath the eastern continental margin of India inferred from joint analysis of gravity, bathymetry and seismic data

[ABS-10-0172]

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The Eastern Continental Margin of India (ECMI) evolved from the breakup of eastern Gondwanaland in the Early Cretaceous period (~130 Ma) and subsequent drifting of Greater India from Elan Bank - Antarctica around 120 Ma. As a result, the lithosphere beneath the ECMI underwent unique evolution, characterized by at least two significant phases of rifting episodes. To understand the rift processes and segmentations on passive margin systems, it is essential to study the broad structure of the lithosphere beneath the region. However, the presence of thick sediment layers from the world's largest sedimentary fan, the Bengal fan, obscures a better understanding of the lithospheric structure and geodynamic processes that led to the formation of ECMI. In this study, we analysed bathymetry, free-air gravity anomaly, and seismic-derived sediment thickness data along three different segments in the southern, middle, and northern parts of the ECMI. We investigated the variations in the crustal and upper mantle structure along the ECMI, leading to a better understanding of structural heterogeneities in the region and the development of suitable tectonic models.

Keywords: Passive Margin, Eastern Continental Margin Of India, Lithospheric Structure, Geodynamics, Bengal Fan

Characterisation of organic matter in marine sediments offshore Mahanadi basin

[ABS-10-0102]

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Characterisation of organic matter (OM) content in marine sediments is vital for understanding the source, nature, degradation, preservation of OM, potential for generation of hydrocarbons and hydrocarbon exploration (Hedges and Keil 1995; Khan et al., 2012; Hare et al. 2014; Ratnayake et al. 2018). The offshore reservoirs play a crucial role in the fulfilment of the energy needs of the nation. Although, the Mahanadi Basin is well explored for the characterization of inland reservoirs (coal, coal-bed methane (CBM) & shale gas exploration), however, the integration of offshore reservoirs for hydrocarbon potentiality is largely overlooked. In the present study, source of the organic matter and its potential to generate hydrocarbons in marine sediments were evaluated. For the characterisation OM in the offshore Mahanadi basin, TOC, TIC, TOC/TN, Rock-Eval pyrolysis and bulk carbon isotopic analyses have been carried out. The results from Rock-Eval pyrolysis reveal that the studied sediment have Type III-IV kerogen, with poor-good TOC values (0.61–1.71 wt. %). The hydrogen index parameter of the studied samples indicates that the organic matter is mainly prone to gaseous hydrocarbons. Although, the fluctuations in Tmax values suggest the immature and mature nature of the organic matter. The organic matters are derived from marine and terrestrial sources as indicated by TOC/TNmolar ratios and δ13CTOC values.

Keywords: Marine Sediments, Hydrocarbon Potential, Pyrolysis, Total Organic Matter

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Remnants of Reunion-Deccan hotspot volcanism in Alleppey Terrace, Kerala offshore, India

[ABS-10-0166]

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The Arabian Sea consists of prominent undersea bathymetric high features and the genesis of these bathymetric highs is connected to the Marion or Reunion hot spot volcanism. Alleppey Terrace is one of the significant bathymetric highs located in the southwestern continental margin of India. Its origin however remained speculative. In this work, we made an attempt to decipher its origin by studying the terrace and the adjacent shelf sediments using major/trace elements, and Sr-Nd isotope geochemistry and further discuss its tectonic implications. Geochemical data suggest that the Alleppey Terrace sediments are distinct from the adjacent shelf. Sediment geochemistry also suggests that Alleppey Terrace was most likely exposed to the atmosphere during low sea level periods in the past and underwent subaerial weathering and lateritization. The εNd values in Alleppey Terrace (range -17.1 to -10.9; avg: -12.7 ± 2.5) are significantly more radiogenic than the shelf (range -26.4 to -22.2; avg: -24 ± 1.3), suggesting the sediments in Alleppey Terrace may be attributed to the basalt rock-derived whereas less radiogenic in Alleppey shelf mostly from the terrigenous flux from southwestern India. Alleppey Terrace contains a juvenile basaltic component, likely derived from in situ weathering of local seafloor. Using geochemical and isotopic proxies, we demonstrate that the terrace sediments are compositionally similar to the Deccan/Reunion rocks. We propose that Alleppey Terrace bathymetric high feature is the product of Reunion plume activity and formed within the time frame of adjacent Laccadive-Maldive-Chagos Ridge (55 ¿ 45 Ma).

Keywords: Reunion, Cretaceous volcanism, Deccan, Southwest India, Hotspot volcanism

Rock magnetic evidence of sedimentary magnetic anomaly along the continental shelf of India

[ABS-10-0029]

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The present study aimed at elucidating the control of geological and climatic processes on the evolution of shelf sedimentary system since Holocene. Rockmagnetic and granulometry data provided evidences on the anomalous sediment magnetic zone which appear to be widespread feature and extends throughout the western continental shelf of India. Changes in the composition of magnetic particles is mainly linked with variability in the supply, transport, and deposition of terrigenous sediments through Holocene. We identified two distinct magnetic zones which are marked by higher magnetite concentration and coarser size clastic sediments. These zones can be very well attributed to the periods of increased detrital supply to the shelf region. End-member analyses of rock magnetic and grain size parameters of sediment core helped to delineate the contributions of primary (terrigenous fluxes) and secondary (diagenetic/authigenic) magnetic signals to the bulk sediment magnetic record.

Keywords: Rock Magnetism, Marine Sediments, Holocene, Sediment Magnetism, Magnetite-rich Band

The occurrences of a submarine mud volcano and its association with palaeo-methane seepage events in the southern Andaman Forearc basin

[ABS-10-0149]

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Submarine mud volcanoes (SMVs) are tectono-sedimentary structures commonly associated with hydrocarbon reservoirs and globally distributed in tectonically active and passive plate margins. These are also known as sedimentary volcanoes, which act as a natural window to deep-seated sedimentary rocks. Stratigraphically, the Andaman forearc basin consists of Quaternary to Paleogene sediment deposits and considered as habitat for hydrocarbon reservoirs. Therefore, the geotectonic settings in the southern Andaman forearc basin (SAFB) offer favorable conditions for the formation of SMVs. Here, we report the occurrences of SMV in the SAFB for the first time and identify their association with paleo-methane seepage events. The inferences made in this study are based on the geological and geochemical characteristics of mud breccia and authigenic carbonates recovered from sediment cores (water depth: ~1600 m; lat: 9.70276°N, long: 93.10508°E) collected onboard SSD085 (RV Sindhu Sadhna) from the SAFB in November 2021. The sediment cores were loaded with chaotic mud breccia and authigenic carbonates varying in size from millimeter to centimeter scale. The megascopic and stereomicroscopic study of the mud breccia shows the massive to thinly layered sedimentary structures and diagenetic pyrite crystals. The stable carbon isotope ratios (δ13C) of authigenic carbonates are highly negative and vary from -31.9 to -46 VPDB, suggesting the possible influence of both biogenic and thermogenic methane during carbonates precipitation. The occurrences of chaotic mud breccia and their high TOC content, Thyasiridae bivalve shell belonging to a chemosynthetic community, and authigenic carbonates with highly depleted δ13C values strongly support the presence of SMVs and their association with palaeo-methane seepage events in the SAFB.

Keywords: Mud Volcano, Mud Breccia, Authigenic Carbonate, Palaeo-Methane Seepages.

Biogeochemical and molecular signatures of microbial activities in cold seep sediments off Cauvery-Mannar basin, India

[ABS-10-0145]

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Marine cold seeps are the ocean-floor manifestation of hydrogen sulfide, methane, and other hydrocarbon-rich fluid emissions across the sediment-water interface at cold bottom water temperature conditions. Methane cold seeps sustain an endemic ecosystem consisting of huge biomass of chemosynthetic organisms and associated heterotrophic fauna. Anaerobic oxidation of methane (AOM) coupled with sulfate reduction mediated by a syntrophic consortium of methane-oxidizing archaea (ANME) and sulfate-reducing bacteria (SRB) are the main biogeochemical processes that play an important role in carbon cycling in methane cold seep sediments. In the present study, a detailed organic geochemical investigation has been carried out to characterize the organic matter sources and AOM-related lipid biomarker patterns in a 3.5 m long, gas hydrate-bearing sediment core SSD070/GC5 collected at a water depth of 1648 mbsf from a recently discovered active cold seep site off Cauvery-Mannar basin. The total organic carbon (TOC) and total nitrogen (TN) profile of the studied core shows parallel trends and a strong positive correlation. The average molar TOC/TN ratio (11.8 ± 2.12; n=328) and the δ13CTOC values of the sediment (-19.2 to -21.8 ¿.) indicate a significant contribution of marine organic matter to the sediments. This is further supported by the n-alkane distribution pattern which shows a strong predominance of short and mid-chain n alkanes and the absence of any odd over even carbon preferences in the high carbon number range of n-C25 to n-C33. The fatty acid compositions are dominated by short chain homologous with a maximum at C16:0 followed by C18:0 and show a strong even over odd carbon number preference. Such distribution patterns of fatty acids also suggest domination of marine input to the sedimentary organic matter. The authigenic carbonate-rich zones with very depleted δ13C values provide evidence of past methane seepages and AOM

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activities. Irregular isoprenoids i.e., 2,6,11,15-tetramethyl hexadecane (crocetane) and 2,6,10,15,19-pentamethylocosane (PMI), which are diagnostic biomarkers of methanotrophic archaea/methanogens, have been identified in some samples based on its retention time and typical m/z in GC-MS. The presence of these biomarkers in the sediment further supports AOM-mediated microbial activities at the seep site.

Keywords: Cold Seep, AOM, Biomarkers, Authigenic Carbonate, PMI

Fe-sulfidization controls Mo concentrations and isotopes in methane-seep sediments

[ABS-10-0146]

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Molybdenum (Mo) concentrations and isotope ratios have been used as a proxy for the paleo-redox conditions of marine sediment. Sources of Mo in marine sediments include adsorption onto Mn-Fe oxyhydroxides, organic matter from seawater, thiomolybdate species (MoO4-xSx2-), and crustal detritus. To understand the Mo systematics in the cold seep region, we have collected the cores from the cold seep site at a water depth of 1760 mbsl during the scientific expedition ORV Sindhu Sadhana (SSD-045) carried out in the Bay of Bengal, eastern continental margins of India. The presence of methane gas flares and chemosynthetic organisms in the study area indicates active methane seepage. It is well known that due to the methane-seepage, the AOM process dominates over the OSR in cold seep environments resulting in H2S enrichment in the sediment pore waters. Hydrogen sulfide is mostly consumed via the burial of Fe-sulfide (AVS and pyrite), organically-bound sulfur, and oxidation to SO42-, S0, or intermediate sulfur oxyanions. In the present study, we have analyzed Mo and pyrite contents coupled with the pyrite-S and Mo-isotope ratios in the core SSD45-4. The Mo concentrations range from 1.0 to 17.4 ppm, pyrite-S contents range from 0.13 to 2.54 wt % and δ98MoNIST-3134 ratios vary from 1.0 to 17.4 ppm, and +0.3 to +2.4 ¿ (δ34pyrite-S) range from -38.5 to +9.0 (¿VCDT). Enhanced Mo concentrations relative to the crustal abundance (1-2ppm) are likely related to the burial of Mo-S species representing paleo-sulfidic events. Whereas, the markedly low δ34S ratios indicate sulfidation near the sediment-water interface. Since all Mo concentration enrichment (relative UCC) peaks correspond to 34S-depleted-pyrite -S, it may be concluded that the Mo enrichment is coupled with sulfide enrichment at the sediment-water interface. The δ98Mosed isotope ratios approaching that of seawater δ98MoSW (δ98MoSW 2.3¿) suggest dissolved Mo(SW) as the dominant Mo source. Whereas lower δ98Mo values are suggestive of multiple sources of Mo including, Mn-

Fe oxyhydroxide minerals, seawater Mo, and/or organically bound Mo. We conclude that the coupling of Mo enrichment and 34S isotope ratios (δ34S pyrite-S) could be a potent indicator of sediment-water interface redox conditions instead of δ98Mo isotope ratio

Keywords: Molybdenum, Pyrite, AOM, Methane Seepage

Evidence of repeated intensification of methane flux from cold seep authigenic carbonates off Cauvery-Mannar basin

[ABS-10-0151]

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Active methane seepage and associated chemosynthetic ecosystem have recently been reported from Cauvery-Mannar Basin by Mazumdar et al., (2020). Here we report pore fluid and authigenic carbonate composition to understand the genesis of the carbonates minerals in a sediment core (SSD70GC5) from the active methane seepage site. The seep sites are characterized by high concentrations of methane (minor ethane and propane), high H2S concentrations, and chemosynthetic organisms including Lamellibrachia tube worm, aragonite-rich carbonate crust, and high magnesium carbonate concretions. Based on sulfate and methane pore-water concentration profiles, the sulfate methane transition zone (SMTZ) was demarcated within 35 to 50 cmbsf. The high concentration of hydrogen sulfide (3.8 to 12.9 mM) and headspace methane concentration (123 to 3521µM) in the sediment pore waters might be responsible for the existence and growth of chemo-symbiont-bearing tubeworm and other seep biotas. A wide range of d13CCH4 values -27.5 to -111.5 ¿ (VPDB) coupled with the presence of ethane and propane shows the most likely mixing of thermogenic and biogenic methane. The total organic carbon (TOC) content is 1.1 to 5.74 wt%. The Total CaCO3 content range from 9.5 to 88.5 wt %. The d13C value of the authigenic carbonates ranges from -20 to -42 ¿ (VPDB). Apparently, the bulk d13C total inorganic carbon (TIC) values are influenced by the high content of foraminifera. Based on carbonate content and carbon isotope ratios multiple zones of methanogenic-carbonate concretions were identified. Enhanced methane flux and sulfate-induced anaerobic oxidation of methane (AOM) would increase the bicarbonate concentrations in the pore fluid leading to the precipitation of CaCO3 (Eq.1 and 2). CH4 + SO42¿ --> HCO3- + HS- + H2O Eq.1 (Boetius et al., 2000) HCO3- + Ca2+ --> CaCO3 + H+ Eq.2 The methanogenic carbonate concretions are dominantly high magnesium calcites typically form at low porewater SO42- and low H2S conditions.

Keywords: Cold Seep, Chemosynthetic Community, AOM, Authigenic Carbonate

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Fatty acid characterization in chemosynthetic organisms of cold seep sites of Krishna Godavari basin, Bay of Bengal

[ABS-10-0316]

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Active cold seep sites (900-1800 mbsl) characterised with gas flares in water column, shallow (<2-3 mbsf) gas hydrates, an ecosystem comprising of chemosymbiont bearing Bivalves (Vesicomidae, Mytilidae,Thyasiridae and Solemyidae families); Polychaetes (Siboglinidae family) and Gastropods (Provannidae family) were discovered from Krishna-Godavari basin, Bay of Bengal (Mazumdar et al., 2019). Benthic fauna including chemosymbiotic bivalves (genera Bathymodiolus, Acharax, Conchocele), polychaetes (genus Sclerolinum), and heterotrophs (gastropods: Provannidae family; squat lobster: Munidopsidae/ Galatheidae; Goose barnacle: genus Neolepas; Brittle star: genus Amphiodia) were sampled and studied to understand the trophic structure of the ecosystem (Peketi et al., 2022). Carbon isotopic ratios of the soft tissues (gill, mantle, and foot) of multiple species such as Bathymodiolus and Acharax showed methanotrophic pathway is predominant in Bathymodiolus and Acharax follow thiotrophic pathway to carry out their metabolic activities (Peketi et al., 2022). To further understand the metabolic processes in the Bathymodiolus and Acharax, fatty acids from the gill and foot tissues of Bathymodiolus and Acharax were extracted and analysed on GC-MS and IRMS. Gill tissues of Bathymodiolus shows the presence of fatty acids ranging from C7:0 to C23:0 in which even-numbered carbon fatty acids are more predominant. Apart from the saturated fatty acids, polyunsaturated fatty acids such as C16:1n7, C18:1(n-13+n8), C18:3n6, and C20:1 were identified in the gill tissues of Bathymodiolus species. In Acharax foot tissues, saturated and unsaturated fatty acids were identified, whereas mantle tissues have saturated fatty acids only. Both Bathymodiolus and Acharax fatty acids profiles show dominance of even-numbered fatty acids. Compound-specific isotope ratios of the fatty acids show highly depleted carbon

isotope ratios (< -80 ¿) for Bathymodiolus whereas for Acharax the carbon isotope ratios are enriched (> -35¿). The depleted carbon isotope ratios in Bathymodiolus may be attributed to the depleted carbon source (methane, 13δC< -90 ¿) accumulated via methanotrophic pathway whereas enriched carbon isotope ratios in Acharax may be attributed to an enriched carbon source (dissolved inorganic carbon) accumulated via thiotrophic pathway.

Keywords: Methane, Cold Seep, Bathymodiolus, Acharax, Carbon Isotope Ratios, Fatty Acids.

Influence of seabed morphology on nodule occurrence in Central Indian Ocean basin

[ABS-10-0123]

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Ocean Mineral Explorer (OMe-6000) is India's first 6000m depth rated Autonomous Underwater Vehicle (AUV), deployed by National Institute of Ocean Technology (NIOT) in the Central Indian Ocean Basin(CIOB) manganese nodule site to study bathymetry and environmental parameters for understanding the nodule distribution pattern. The OMe-6000 is a fully augmented hydrographic and geophysical exploratory tool with a variety of scientific and survey payloads for deep ocean research. AUV-based high-resolution bathymetry and optical images from the manganese-nodule (Mn-nodule) region in the CIOB are examined in detail for understanding the influence of seabed features on nodule occurrence. Manganese nodules are a futuristic source of metals in international waters. The influence of the morphology of the ocean floor on nodule distribution and abundance is analysed using high-resolution AUV-based bathymetry collected at 5270 m water depth and ground truth from photographs collected. Backscatter data from multibeam sonar was studied to understand the sediment type in the nodule field, which will aid in understanding the sedimentation rate and thereby the nodule distribution. Sub-bottom profiler output and magnetic anomalies in the region were studied to find the influence of these outcrops on nodule distribution. The nodules are distributed along the flanks and slopes of the seamounts due to the availability of rock fragments from seamounts and abyssal hills, rock outcrops and crust exposures, which act as nuclei favourable for nodule growth. Partial to complete burial of nodules under the sediments was observed in the plains and valleys. In low-lying locations, sediment transfer from abyssal hills into nearby valleys results in faster sedimentation and prevents nodule development. Backscatter data shows the presence of soft sediments in the valley, resulting in the burial of nodules. Nodules are effectively cut off from the geochemical conditions on the sediment surface when they are buried. Magnetic data shows positive anomaly over the hilly region, which

indicates that the rocks in the hills have a higher magnetic susceptibility or contain magnetic minerals. The intrusive plugs under these hills could be the reason for this anomaly, which is evident from the sub-bottom data. These minerals may favour the formation and deposition of nodules in their flanks.

Keywords: Manganese-Nodule(Mn-Nodule), AUV-Based High-Resolution Bathymetry, Backscatter Data, Sub-Bottom Profiler, Magnetic Anomalies

Role of Bioturbation in the sediment water interface for the Manganese nodules abundance in the Central Indian Ocean basin

[ABS-10-0108]

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Polymetallic manganese nodules are rich deep sea mineral resources with high concentrations of Mn, Fe, Co, Ni, REE in oxide form. Nodules are known to occur on the deep-sea floor as a result of variety of processes, including hydrogenous, diagenetic, microbiological, chemical absorption, etc. with shark teeth and basalt fragments as the nuclei for the accretion of minerals. To understand the mechanism involved in the abundance of nodules on the seafloor, an attempt is made to understand the bioturbation process by the biological community from the deep sea floor of the Central Indian Ocean Basin collected from the Autonomous Underwater Vehicle (Ocean Mineral Explorer, OMe-6000). It captured images during the exploration sea trials done in December 2022 at 5270 m water depth. Interestingly, the abyssal benthic community of the central Indian Ocean basin indicates the existence of organisms exceeding 2 metres in length. Optical images from the AUV identified two dominant benthic organisms: Tergivelum cinnabarinum and Yoda purpurata. These animals displayed distinctive behaviour, creating a strip of sediment as they moved in a curly direction and consistently lifting off the trace they left behind. The underwater images captured this mechanism, highlighting the significance of the organisms' slow movement. T. cinnabarinum did not demonstrate drifting or lifting off from the sediments, but its abundance was also recorded on the seafloor. The nodules serve as barrier to organismal movement and these organisms are less frequently found beneath the nodule compared to the surrounding area, resulting in reduced sediment motion. For the deep-sea benthic community, the primary source of food is particulate organic carbon that falls from above. Nodules act as umbrellas, intercepting the descending food particles. During a process called wedging, organisms create tunnels beneath the nodules, causing displacement of materials

and lifting of manganese nodules. If these tunnels become filled with sediment, the nodule will remain elevated. It was observed that organisms can burrow under the nodules and deposit castings to one side, causing the nodules to subside. Therefore, considering the combined effects of all types of bioturbation, it is crucial to understand how bioturbation supports nodules at the sediment surface.

Keywords: Autonomous Under Water Vehicle, Polymetallic Nodules, Bioturbation

The potential of seismic quiescence and B value as possible precursors in the Andaman-Sumatra region

[ABS-10-0184]

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The Andaman-Sumatra region was hit by a catastrophic megathrust earthquake on December 26, 2004, with a magnitude of approximately 9.3 (Mw), resulting in a death toll of approximately 225,000 people and a rupture of 1,300 kilometers. The occurrence of a massive tsunami triggered by this earthquake has led to an increased interest in studying earthquake patterns and identifying potential seismic precursors for earthquake forecasting purposes. The approach of Probabilistic Seismic Hazard Assessment (PSHA) is utilized in this paper to assess the probability and intensity of potential earthquakes in the study area by utilizing seismicity data. The earthquake data obtained from the International Seismological Center catalog, covering the period from 1900 to 2020 has been utilized to estimate earthquake recurrence rates and magnitudes. The dataset was analyzed by dividing the study area into various epicentral blocks using a division of 4 degrees and an overlapping of 2 degrees within each epicentral block. Observation of the distinct stages of various seismic cycles was made in each of the epicentral blocks. The seismic cycle is comprised of different phases, namely the mainshock period which is also known as co-seismic, a subsequent phase called post-seismic or Q1, a pre-seismic period characterized by an elevated level of seismic activity, and an inter-seismic period referred to as Q2. The relationship between earthquake frequency and magnitude for each epicentral block was analyzed by utilizing the b-value obtained from the Gutenberg-Richter relation for each stage of the seismic cycle. The study suggests that long-term quiescence leads to great earthquakes. The study also proposes that the area between 2°N and 6°N latitudes witnesses a long-term quiescence which may lead to a major earthquake in the near future.

Keywords: Earthquake Precursors, B-Value, Seismic Quiescence

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Comparing shipborne echo-sounding data with global bathymetry grids, and tracing the surface channels in the Bay of Bengal

[ABS-10-0118]

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The Bay of Bengal is carpeted by the Bengal Fan formed due to the huge sediment load brought in by the Ganga-Brahmaputra river system draining the Himalayas via the submarine canyon Swatch of No Ground. A network of surface channels is responsible for the distribution of these sediments throughout the Bay of Bengal as far as south of the equator. Thus the Bay of Bengal is characterised with smooth topography which is occasionally cut by the prominent surface channels. About 30,000 line km of echosounding data collected using single beam echosounder during four cruises of ORV Sagar Kanya in the 1990's is used in the present study. Further, the echosounding and parasound data collected during RV Sindhu Sadhana cruise 21 is also used. This dataset is used for two purposes: 1. to compare with the global bathymetry grids, and 2. to trace the surface channels in the Bay of Bengal. The echosounding data was first edited for any spurious values. The dataset was then scanned for the irregular topography belonging to the channels. Thereafter the channels were identified as per the nomenclature of Curray et al., 2003. The active channel and the abandoned channels W1 to W6, and E1 to E7 were traced along the tracks. These channels were studied in detail in terms of their dimensions, symmetry, levee formation, etc. This study helped to refine the locations of the channels in the Bay of Bengal. Further, the parasound data was used to reveal the subsurface stratification around some of the channels. Comparison of this shipborne dataset with the global grids reveals there is a good match between these datasets whenever the bathymetry is even. Large discrepancies are seen when the topography is irregular as on ridges or seamounts.

Keywords: Bay Of Bengal, Channel, Echo-Sounding Data, Bathymetry Grids, Parasound Data

Assessing structural deformation history in the Central Indian Ocean using multi-channel seismic reflection data
[ABS-10-0250]

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The central Indian Ocean is known for its complex intra-plate deformations, making it a subject of great intrigue and ongoing debate among researchers. Despite numerous studies dedicated to unraveling this phenomenon, there still needs to be a consensus on its structural characteristics and spatiotemporal origin. Previous geophysical and deep-sea drilling investigations suggested that extensive crustal deformation commenced in the late Miocene. However, subsequently an earlier initiation of deformation has been envisaged, dating back to approximately 15.4-13.9 million years ago. This change has been attributed to the concurrent dynamics of the India-Eurasia convergence. Another hypothesis posits that temporal variations in the rotational motion of the India-Somalia-Capricorn plates may have played a crucial role in extensive crustal deformations. To shed further light on this enigmatic region, we conducted a comprehensive analysis utilizing new deep penetrating multi-channel seismic reflection data from the central Indian Ocean. We aimed to characterize the style and extent of structural deformations and investigate potential mechanisms underlying their occurrence. Through seismic-stratigraphic interpretation and cumulative fault-throw analyses of the newly acquired regional seismic profiles, we offer valuable insights into the evolution of intra-plate deformations. Our study confirms extensive faulting occurred during the early Miocene across the Central Indian Deformation Zone (CIDZ). We reassess the structural deformations and infer that approximately 40% of the faults were activated around or before the early Miocene, with the greatest displacement occurring at a regional unconformity dating back to 17-18 Ma. Such extent of deformation is significantly higher than the previous estimates. Furthermore, we identify distinct categories of deformation manifested within these faults. These findings provide substantial evidence supporting an onset

of deformation well before the late Miocene time. The new subsurface images obtained through our investigation offer improved constraints on the region's prominent stratigraphic and structural variations. By integrating seismic data with other geological and geophysical datasets, we have made significant progress in enhancing our understanding of the central Indian Ocean's complex deformations.

Keywords: Intra-Plate Deformation, Central Indian Ocean, Multi-Channel Seismic Data, Early Miocene

Sub-Theme-11

Polar Science and Cryosphere Studies

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Decennary variability and regulating processes in Kongsfjorden, an Arctic fjord

[ABS-11-0318]

Divya David T*, N. Anilkumar, Teesha Mathew, Renjith V. R, M. Ravichandran
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West Svalbard fjords reflect and respond more to changes the eastern Arctic undergoes. One among them, Kongsfjorden, shows a warming and salinification trend over the last few decades for which a major reason is higher Atlantic water (AW) volumes than the fjords south of it. NCPOR has been monitoring Kongsfjorden since 2011, and the water column temperature and salinity showed an increase embedded with a strong inter-annual variability. The summer water temperature increased by 0.09oC/yr on the open ocean side and 0.12oC/yr on the glacier side. The higher rate of warming at the glacier side explains the reported rise in basal glacial melting over recent times, driven by increased AW near the glaciers. Further, the rate of temperature increase was found more in winter (0.15oC/yr) than in summer. The time series mooring data showed that with high interannual variability in the residence period of AW in the fjord, its presence was found generally from summer to autumn when the North Atlantic Oscillation (NAO) was positive. The pattern persisted until winter in 2014, 2015, and 2016. The NAO caused by the difference in sea-level atmospheric pressure over the North Atlantic Ocean in its positive phase shifts the storm tracks northward, enhancing AW flows to the Arctic Ocean. On its way, it enters west Svalbard fjords, including Kongsfjorden, under favourable conditions at the mouth, inducing high variability in the hydrographic and biogeochemical conditions in the fjord. The AW intrusions were weaker when NAO and Arctic Oscillation were strongly negative. Further, it is found that the upper water column temperature and salinity were in anti-phase with NAO, mainly due to the upper layer glacial melt freshwater outflow compensating deeper AW flow into the fjord that happens during positive NAO. The AW temperature was in phase with NAO in 2015, 2016, and 2017 at a periodicity of 300-420 days when the AW was dominant in the fjord. The study could decipher the effects of NAO phases on Kongsfjorden variabilities during the last decade, which could act as baseline information to further investigate how the regional variabilities influence the region.

Keywords: Arctic Ocean, Fjords, Atlantification, Warming, NAO

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Spatial and temporal variability of extreme precipitation events in Dronning Maud Land, East Antarctica: Insights from high-resolution data and a case Study

[ABS-11-0499]

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xtreme precipitation events (EPEs) are severe weather conditions that cause unusually large amounts of rain or snow, leading to natural disasters. EPEs are crucial in Antarctica, impacting the Antarctic ice sheet's surface mass balance and stability. This study investigates the spatial and temporal variability of EPEs in Antarctica's Dronning Maud Land (DML) sector, focusing on their occurrence, spatial distribution, and underlying mechanisms. High-resolution atmospheric data from the ECMWF ERA5 reanalysis and a specialised high-resolution atmospheric model (Polar WRF) optimised for polar regions are utilised. A detailed case study of an intense precipitation event on November 8th and 9th, 2015, which contributed 22% of the total annual precipitation within 24 hours, is also conducted. Our findings reveal that EPEs are most prevalent in regions of complex topography along the coastal area and high-elevation regions in the interior, where moist air masses interact with orography. Around 40% of the EPEs in DML are associated with atmospheric rivers (ARs), narrow bands of moist air originating from subtropical latitudes that result in the highest daily precipitation values. An analysis spanning 1979-2018 demonstrates a statistically significant increase in the number of EPEs per year and increased precipitation from EPEs in much of DML. These trends are linked to changes in moisture availability and favourable meridional winds in the Atlantic sector of the Southern Ocean. The case study highlights the role of a record-strength blocking high-pressure ridge, which effectively obstructed and facilitated the poleward movement of a deep low-pressure cyclone, enabling the transport of subtropical air towards the Antarctic interior. Notably, an anomalously strong atmospheric river was observed from the South Atlantic Ocean on November 7th, 2015 and advecting air poleward from 30-40°S. The

primary moisture source was identified as an area of anomalous evaporation in the South Atlantic Ocean several days before the event. The model output indicates that precipitation was concentrated in regions with steep topography along the path of the atmospheric river. This study underscores the increasing trends in EPEs and ARs over DML, closely linked to the behaviour of the warming South Atlantic Ocean, identified as a significant moisture source during these precipitation events. Understanding the dynamics and impacts of EPEs is crucial for comprehending the future response of the Antarctic ice sheet to changing climate conditions. This study highlights the importance of accurately predicting the warming and changing conditions of the Southern Ocean to enhance our understanding of their impact on polar regions. This work emphazises the need of a predicted ocean where society understands and can respond to changing ocean conditions? as per goal of UN Decade of Ocean Science.

Keywords: Extreme Precipitation Events, Atmospheric Rivers, Evaporation, Polar WRF, Antarctica

Dynamics of total organic carbon and apparent Oxygen utilization across the fronts in the Indian sector of Southern Ocean during austral summer
[ABS-11-0213]

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The Southern Ocean is unique due to its seasonal and extreme environmental conditions, which also makes it important with regard to the carbon dynamics and sequestration that influence global changes. Total Organic Carbon (TOC) present in its different forms in the ocean, play a crucial role in various biogeochemical processes and the carbon cycle in the ocean. This study discusses the variability of TOC along a meridional transects across the different fronts in the Indian sector of the Southern Ocean (ISSO). Seawater samples for TOC, Dissolved oxygen and other biochemical variables were collected during austral summer. During the study periods, TOC concentration varied from 80μM to 155μM with a considerable inter-annual difference during consequent austral summers. The observations showed clear latitudinal patterns and the highest TOC were observed at the Subtropical front (avg. 116 μM) with a decline at the polar front-I (avg. 88 μM), also a significant decrease was noted with depth. The POC:TOC ratio also varied considerably over the study period and within the water column, suggesting the partitioning of organic carbon into its dissolved phase. This study implied that the phytoplankton productivity and microbial activity contributed significantly to the TOC especially in terms of the POC variability across the fronts and with depth in the ISSO. The significant correlation of TOC with temperature and AOU suggests that physical mixing process and its inter-play with the biochemical processes considerably influence the TOC variability, besides different water masses and hydrographic features like eddy are contributing factors to the dynamics of TOC across the fronts of the ISSO.

Keywords: Southern Ocean, Fronts, Total Organic Carbon, Apparent Oxygen Utilization, Remineralization

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Hydrography and zooplankton assemblages in coastal waters of Antarctica during the sea ice melting season

[ABS-11-0033]

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Zooplankton plays crucial roles in the structure and functions of aquatic ecosystems, which include maintaining biodiversity, energy transfers, and balance the trophic structure. Information on the numerical abundance, species diversity and vertical distribution of zooplankton are inadequate in coastal Antarctica. To address this shortage of information, the vertical structures of the zooplankton community between the surface and 1000 m were investigated along with hydrographic features in the austral summer of 2017. Surface temperature was high in the open ocean region, followed by the neritic and continental shelf regions. In contrast, nutrients were higher in the continental shelf than in open ocean and neritic zones. The mixed layer depth was shallower in the neritic zone than in continental shelf and open ocean zones. Antarctica surface water, winter water, dense shelf water and modified circumpolar deep water are the key water masses in the studied area. High zooplankton biovolume was associated with high chlorophyll-a areas. Overall, the zooplankton biovolume in the mixed layer was high. The total zooplankton biovolume was mostly made up of calanoids and cyclopoids, which accounted for 81% of the total zooplankton count. In addition to the copepods, chaetognaths and appendicularians were found to be the next most abundant taxa, showed their importance in the mesopelagic and bathypelagic layers. Calanus simillimus and Calanus australis were showed their importance in the oceanic region, where Stephos longipes is an indicator species in the shelf region associated with floating sea ice. Calanoides acutus, Calanus propinquus, and Oithona spp. were the most common taxa in the neritic zone. We assumed that the combination of provincial features, such as sea surface temperature, food availability and sea ice cover, implying that different environmental characteristics may have the greatest impact on the zooplankton abundance and species diversity in the coastal waters of Antarctica.

Keywords: Coastal Antarctica, Water Masses, Hydrography, Copepods, Sea Ice

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Investigating the Teleconnection between Spring Arctic Sea ice and Indian Summer Monsoon Rainfall

[ABS-11-0320]

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The relationship between Arctic sea ice concentration (SIC) and Indian summer monsoon rainfall (ISMR) has gained significant attention due to its impact on the Earth's climate system. The present study employs statistical and dynamical analysis using passive microwave sea ice data to elucidate the relationship between Arctic SIC and ISMR from 1979 to 2021 on seasonal scale. The singular value decomposition (SVD) analysis reveals maximum total variance of 41.1% between spring Arctic SIC and ISMR. Additionally, empirical orthogonal functions (EOF) analysis highlights the leading mode (PC1) of ISMR, explaining 32% of the variance and exhibiting significant variability across different regions. Further, a notable inverse correlation is observed between ISMR PC1 and Arctic spring SIC in both the Central Arctic ($r = 0.51$, $p>0.05$) and the Barents-Kara Sea ($r = -0.39$, $p>0.05$). These findings suggest that increased ISMR is associated with enhanced SIC in the central Arctic due to the influence of circumglobal teleconnections (CGT). The study demonstrates that the Rossby wave pattern and the formation of troughs and ridges across the Northern Hemisphere play a substantial role in influencing the variability of ISMR in response to changes in Arctic SIC. This highlights the interconnectedness of these climatic factors and their impact on the monsoon system. Importantly, the research confirms that SIC exhibits a long memory, implying that changes in Arctic sea ice conditions have a lasting effect on subsequent ISMR patterns. These findings emphasize the importance of understanding and monitoring Arctic SIC as a potential indicator for predicting and assessing variations in Indian summer monsoon rainfall.

Keywords: Sea Ice Concentration, Ice-Atmosphere Interaction, Circumglobal Teleconnections, Rossby Wave

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Unraveling the connection: The Role of Ocean-Atmosphere response in the unprecedented decline in the Antarctic Sea ice

[ABS-11-0322]

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Over the coming century, Antarctic Sea ice is expected to experience a significant decline due to increasing greenhouse gas concentrations. The expansion and recession of Antarctic Sea ice exhibit regional and temporal variations. Scientists have been closely monitoring Antarctic Sea ice through satellite measurements and other methods to track its extent and behavior. From 1979 until 2015, there was an overall increase in Antarctic Sea ice extent (SIE) over a decade, but recent years have seen a rapid loss. This study identifies the ocean-atmospheric forcing and climate fluctuations responsible for the record-low SIE in February 2022 and 2023. In February 2022, the SIE reached a historically low level of 2.16 × 106 km2, which was 43% lower than the average extent of previous February months during the satellite era. Furthermore, in the austral summer of 2023, the sea ice extent was approximately 30% less than expected for February. Global ocean temperatures are reported to be among the warmest on record. These diminishing sea ice conditions have significant implications for the stability of ice shelves and the rate of sea level rise. Therefore, continuous monitoring of the patterns and ocean-atmospheric factors influencing sea ice variations is of utmost importance.

Keywords: Sea Ice Decline, Sea Ice Concentration, Amundsen Sea Low, Southern Annular Mode

Observational analysis of polar sea ice using satellite passive microwave sea ice concentration data

[ABS-11-0030]

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In polar regions, the sea ice plays a crucial role in the atmosphere and ocean circulation due to its exchange of heat and salinity. To understand the mean and variability in observed sea ice concentration (SIC) data, we have used the observed satellite-derived sea ice concentration data from the Special Sensor Microwave Imagers/Sounders (SSMIS) and Advanced Microwave Scanning Radiometer 2 (AMSR2) products at National Centre for Medium-Range Weather Forecasting (NCMRWF). Both microwave radiometer products were developed based on the Ocean and Sea Ice Satellite Application Facility (OSI SAF) Hybrid Dynamic algorithm (linear combination of Bootstrap and Bristol algorithms). The statistical analysis was performed on the observed satellite data (SSMI16, SSMIS17, SSMI18, and AMSR2) to know the growth and decay of sea ice over both poles (Arctic and Antarctica) during the period of Dec-2022 to Apr-2023. The products were also compared against the independent observations. The equal-weighted ensemble mean was also generated for the different observed satellite sea ice data products. The ensemble mean will also be used for the sea ice data assimilation system at NCMRWF.

Keywords: Polar, Sea Ice, SSMIS, AMSR2, Ensemble Mean

Three-component absorption model for phytoplankton size classes in the Indian Sector of the Southern Ocean

[ABS-11-0064]

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Information on phytoplankton size classes (PSC) is crucial for understanding the abundance of the phytoplankton community, the carbon sequestration capacity of the biological pump, and phytoplankton photosynthetic efficiency in the Southern Ocean (SO). We observed that in the Indian sector of SO (ISSO), chlorophyll-a (Chl-a) values ranged from 0-0.6 (mean <0.3 mg m-3), and aph(443) ranged from 0.001-0.04 m-1 (mean <0.02 m-1). However, the global aph-Chl-a algorithms showed Chl-a values ranged between 0 to 30 mg m-3, and aph ranged between 0.001 to 0.2 m-1, which are significantly higher than that observed in ISSO. Moreover, Hirata et al. (2008) have developed a global absorption model for phytoplankton size classes, which characterized that aph for pico (0.001-0.01 m-1), nano (0.01-0.06 m-1) and for micro (>0.06 m-1) phytoplankton. However, we observed much lesser (aph<0.06 m-1) in the ISSO (mean <0.04 m-1). Hirata's model underperformed while capturing micro and a part of nano phytoplankton in the ISSO. Therefore, we developed a three-component model that calculates the fractional contributions of three phytoplankton size classes (micro-, nano-, and picoplankton) to the overall Chl-a and aph in the ISSO. Diagnostic pigments were used to infer micro, nano, and pico size classification. The present absorption model equations were well-fitted for all PSC in the ISSO. The current models showed less RMSE for nano (0.0004) and microplankton (0.0009) and higher RMSE for picoplankton (0.0003) than Hirata et al. (2008) models. (RMSE: 0.0003 (Pico), 0.001 (Nano)). Furthermore, spatially matched Chl-a data derived from MODIS and SeaWiFS satellites were used to validate the model. This study would facilitate synoptically deriving phytoplankton size classes using space-borne sensors in this remote and relatively inaccessible polar region.

Keywords: Bio-Optics, CDOM Absorption, Phytoplankton Absorption, Phytoplankton Size Class, Pigment Composition, Southern Ocean

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Spatiotemporal evolution of Sea ice and its teleconnections with large-scale climate indices over Antarctica

[ABS-11-0387]

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Sea ice variability patterns are highly influenced by several large-scale ocean-atmospheric oscillations. We have demonstrated the influence of large-scale ocean-atmospheric oscillations on sea ice variability in Antarctica using statistical and wavelet coherence methods. During the past 42 years, the total Southern Ocean Sea ice extent (SIE) has expanded, while the Amundsen-Bellingshausen Sea (ABS) SIE has decreased. Based on our analysis, El Nino Southern Oscillation (ENSO) has a greater impact on Antarctic Sea ice variations than the other three parameters such as Indian Ocean Dipole (IOD) Southern Annular Mode (SAM), and Interdecadal Pacific Oscillation (IPO). A wavelet coherence analysis (WCA) of ENSO and SIE in various sectors revealed an out-of-phase correlation between the Indian Ocean and the Ross Sea. Although the influence of the IOD is more dominant in East Antarctica, the coexistence of the IOD with ENSO has resulted in considerable variations in sea ice coverage in the ABS. It has been observed that the SAM index and ice extent are associated with a dipole pattern, with more ice in the Ross Sea and less ice in the Weddell Sea. We could also observe the alterations in sea ice characteristics following the phase shift of IPO from a positive to a negative after the 1990s.

Keywords: Sea Ice, Climate Change, Antarctica, ENSO, SAM

Paleoclimatic implications from a lake LH73 record of Larsemann Hills, East Antarctica

[ABS-11-0128]

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The lake sediment deposits in the ice free region of Larsemann Hills, East Antarctica can be used as a natural archive to understand the long term variability of the climate system. In this study we use the magnetic properties along with the interparametric ratios (χlf, χfd%, χARM, SIRM, χARM/χlf, SIRM/χlf, χARM/SIRM, S-ratio) and inorganic carbon (carbonate) as proxies from a 115 cm long sediment core which spans for the past 29 kyr from the lake LH 73 located in the Broknes peninsula of the Larsemann Hills. The last glacial period is characterized by high (low) χlf, Inorganic carbon (χARM, SIRM) values, and indicates higher magnetic minerals along with inorganic carbon and low ferrimagnetic grains, the values are almost constant throughout the period which may suggest that the area was under a perennial ice cover rather than a ice sheet that minimized the sedimentation and physical weathering. The transition from the last glacial to the warm Holocene conditions is marked by a shift from the perennial ice cover to a moated ice stage which is indicated by the increase in χlf and SIRM due to the deposition of the wind-blown sediments that was trapped in the cracks which were formed during ice cover. The late Holocene period is characterized by low (high) χlf (χfd%, χARM/χlf, SIRM/χlf) values and indicate a warm condition with pedogenesis taking place and forming superparamagnetic grains along with the formation of authigenic greigite. Additionally, the inorganic carbon has reduced since the last glacial period, indicating that chemical weathering is occurring more frequently than physical/mechanical weathering.

Keywords: Magnetic Susceptibility, Inorganic Carbon, Holocene, Lake Sediments, East Antarctica

Impact of Atmospheric heat flux and Oceanic processes on the interannual variability of Sea ice and sea surface temperature in the Antarctic Ocean

[ABS-11-0195]

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Here, the variation of sea ice in the Antarctic ocean from 2000 to 2019 is studied using an ocean sea-ice coupled model, known as Modular Ocean Model of version 5 with Sea Ice Simulator (MOMSIS). MOMSIS replicates the interannual variation in the sea-ice concentration (SIC) and sea surface temperature (SST) in the Antarctic as observed by the AVHRR almost perfectly during all four seasons; summer (December¿February), autumn (March¿May), winter (June¿August) and spring (September¿November). The Antarctic Ocean is divided into 5 sectors(Weddell Sea(60W¿20E), Indian ocean(20¿90E), Pacific Ocean(90¿160E), Ross Sea (160E¿130W) and Bellingshausen and Amundsen Seas (130¿60W)). A comparison of satellite and model data shows that, between 2000 and 2019, 2016 had the lowest(highest) SIC(SST) across the whole Antarctic ocean during the spring and summer. To comprehend how thermodynamic processes affect changes in SIC and SST, mixed layer heat budget analysis has been done. The strong net atmospheric heat flux(NAH) and the weakened Ocean Vertical Processes (OVP) during the spring and summer of 2016 and autumn and winter of 2017 resulted in increased sea surface temperatures (SST) compared to other years, which is likely to lead to decreased sea ice concentration (SIC) during those respective seasons.

Keywords: SIC, SST, OVP, NAH

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Physical and Biogeochemical features in the Polar, Subantarctic and Subtropical fronts of the Indian sector of the Southern Ocean: Insights from the 8th Indian Southern Ocean Expedition

[ABS-11-0259]

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The multi-disciplinary data collected during the 8th (February 2015) Indian expedition to the Southern Ocean was used to study the physical and biogeochemical features in the polar, subantarctic, and subtropical fronts of the Indian sector of the Southern Ocean (ISSO). Satellite SST data was used to identify the fronts, which revealed that three stations sampled during this expedition were in the southern Polar Front (PF2), four stations in the northern Polar Front (PF1), one in Subantarctic Front (SAF), and one in Subtropical Front (STF). We compared the hydrographic and nutrient profiles from each front with climatology data. Also, the mixed layer depth (MLD) and the stability (E) of the water column were estimated using the hydrographic data. The analysis showed that shallow MLD and strong stratification below the mixed layer were the characteristic features of the STF. However, the high nutrients (mainly silicate and phosphate) compared to climatology and the resultant comparatively high surface and subsurface chlorophyll (Chl)-a showed that eddies can enhance the biological production of the STF by weakening the stratification. The observed low Chl-a in SAF and PF1 may be due to silicate limitation. The deep MLD (~ 75 m), weak stratification, and high concentration of nutrients were observed in the PF2. However, the very low Chl-a indicated that the biological production of the PF2 region was limited by iron during the observation.

Keywords: Mixed Layer Depth, Chlorophyll, Fronts, Eddies, Southern Ocean

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Role of sea surface temperature variability on moisture availability in the Arctic

[ABS-11-0256]

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Precipitation events at Svalbard are often caused by strong horizontal moisture convergence advected from adjacent warm oceanic regions. Here in this study, we attempt to identify the role of sea surface temperature (SST) variability off the Svalbard coast on moisture convergence in Svalbard. To achieve this goal, monthly mean ERA5 reanalysis data was used during the period 1980 - 2020. Investigation of the co-variability between winter (DJF) SST and vertically integrated moisture flux convergence (MFC) indicates that the warm waters carried by West Spitsbergen Current (WSC) off the west coast of Svalbard is a major source of moisture supplied to Svalbard. Singular value decomposition (SVD) analysis suggests the dominant mode of SST and MFC co-variability is characterized by warm SST and strong moisture variability along Atlantic water pathways viz. WSC and Barents Sea Opening branch. This mode explains 90% of the co-variability in these two variables. Further composite analysis of the surface winds over the region favors the transport of moisture. This could lead to precipitation events over Svalbard. The findings show that there is a strong coupling between the MFC at Svalbard and SST in the WSC. Further studies are required to understand the impact of large-scale ocean and atmosphere circulation patterns in regulating these strong ocean-atmosphere coupling in this region.

Keywords: Polar Precipitation, Arctic, Moisture Convergence, Singular Value Decomposition

Sub-Theme-12

Blue Economy

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Reg. ID	Abstract Title	First Author
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ABS-12-0039	An in-silico method for assessing marine natural product's feasibility as targeted therapy for cancer	Mansi Yogasunder
ABS-12-0185	Numerical assessment of the damping coefficient of a wave energy device with a linear power take-off system	Aiswaria K
ABS-12-0476	Blue Economy perspectives for India: Mapping possibilities for sustainable development	Falguni Tailor
ABS-12-0324	Enabling Shrimp Farming through Remote Sensing AI	Parag Gautam Ramteke
ABS-12-0478	Primary productivity for sustainable marine fishery resources ' a precursor for blue economy	Rupam Kalita

Immobilized microalgal consortia - potential bioremediative candidate for the aquaculture wastewater treatment: a sustainable approach towards India’s Blue Economy

[ABS-12-0077]

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The expansion of the aquaculture industry and the fast-growing aquaculture practices have led to aquatic environment pollution and wetland degradation. The aquaculture sector's significance became relevant due to the overexploitation of fisheries resources from inland and marine ecosystems resulting in resource depletion. In India, the expansion of shrimp aquaculture is located majorly along the coastal regions. This involves the vast conversion of wetlands for this purpose which, with time, cause severe loss of soil nutrient quality, water loss, and environmental pollution. The application of indoor culture intensification of species on demand is in a progressive state. This requires the application of bioremediation of wastewater with a systematic approach to maintain the water and cultured species quality. The bioremediation properties of microalgal species have been applied in the treatment of wastewater originating from wide range of industries. The present study employs the application of microalgal species (Chlorella vulgaris & Isochrysis galbana) for the bioremediation of synthetic aquaculture wastewater under immobilized cell conditions. C. vulgaris is well known for phycoremediation and I. galbana used as live feed in the shrimp hatchery for its nutritive value. During the 10-day experiment, compared to individual species, the consortia of these two species depicted better efficiency with respect to the removal of nitrate (77.8%) and phosphate (99%). The microcosm experiments revealed that the microalgal species performed better under immobilized conditions which supports the ease of cell harvest and enhanced survival/storage. This provides insight into the application of microalgal consortia for the bioremediation of aquaculture wastewater. The sustainable application of microalgal consortia will enhance the water quality during intensified aquaculture farming and thereby promote the expansion of the blue economy in our country.

Keywords: Aquaculture, Bioremediation, Microalgae, Immobilization, Wastewater Treatment

An *in silico* method for assessing marine natural product's feasibility as targeted therapy for cancer
[ABS-12-0039]

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In silico methods are gaining the attention of researchers around the globe to facilitate drug discovery. The marine realm offers a multitude of bioactive compounds which are largely unexplored and lay dormant in massive untapped global databases. The present study explores alternate marine-based molecules similar to widely used inhibitor molecules for cancer therapy. Cyclin-dependent kinase 4 (CDK4), known as cell division protein kinase 4, regulates the cellular transition of phases in the cell cycle (G1 to S phase). CDK4 inhibitors effectively block the proliferation of cancer cells. The widely used drugs for inhibiting CDK4 were identified from the DrugBank database hosted by the University of Alberta. The 3D structure of CDK4 is obtained from the protein data bank (PDB ID: 2W9Z), and the inhibitory sites were identified from the literature. We have selected LOTUS, a living database hosting details of diverse molecules from various spectra of the ecosystem, and similar compounds of marine origin were identified. Virtual screening is carried out using molecular docking on AutoDock Vina. This yielded energy-efficient inhibitors to be further analyzed to understand better the molecule. The Density Functional Theory calculations (DFT) were done for the best three natural hits and their corresponding similar drug. The optimization step was carried out on the Gaussian 09 software package from which the HOMO and LUMO profiles were visualised. To evaluate the staility and binding ability of the CDK4 and the ligand, molecular dynamics simulations were carried out using Gromacs software. Finally, the binding free energy of the top three ligands when in complex with the protein was calculated using the molecular mechanics/ Poisson Boltzmann method, which provided more accurate binding energy. We have identified molecules of marine origin [Nortopsentin B and Nortopsentin C (Porifera), and Cyanidin 3-glucoside (Mollusca)] having similar structural and functional properties similar to two widely used cancer-therapy drugs (Abemaciclib and Alvocidib) The in-silico approaches to identifying marine molecules from open-source databases have immense potential in the emerging field of marine pharmaceuticals and in tackling novel and new-age diseases.

Keywords: *In Silico*, Marine Drugs, Cancer, CDK4, Porifera, Blue Biotechnology

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Numerical assessment of the damping coefficient of a wave energy device with a linear power take-off system

[ABS-12-0185]

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The development of efficient wave energy converters suitable to the deployment site is essential to harvest power economically. Estimation of the power take-off damping coefficient is crucial in the performance assessment of wave energy converters. In most of the studies, a constant value of the damping coefficient is chosen for the calculation of power in all wave conditions. The inconsistency involved in such devices¿ performance may also be due to the variation in power take-off damping corresponding to the incident waves. This study focuses on the influence of the damping coefficient on the behaviour of the wave energy device in various wave conditions. It discusses the time domain modelling of a heaving wave energy converter model device with a linear power take-off in regular waves using WEC-Sim software. The ideal values of the damping coefficient corresponding to the maximum power absorption for various wave conditions are presented to illustrate the feasible power take-off configuration for the model.

Keywords: Wave Energy Converter, Power Take-Off, Damping Coefficient, Power Performance, Efficiency.

Blue Economy perspectives for India: Mapping possibilities for sustainable development

[ABS-12-0476]

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India, with its vast coastline and extensive marine space, holds significant potential for unlocking the benefits of the Blue Economy. The World Bank defines the Blue Economy as the "sustainable use of ocean resources for economic growth, improved livelihoods, and jobs while preserving the health of the ocean ecosystem". As a nation, we have embarked on a journey to tap into coastal and marine resources to drive economic growth. This commitment is evident in various governmental initiatives, such as the establishment of a committee by Niti Aayog to draft a National Maritime Policy, the draft Blue Economy Policy formulated by the Ministry of Earth Sciences, the integration of the blue economy into Vision 2030 as one of its ten dimensions, and the Sagarmala Programme. The concept of the blue economy is relatively new in India, but it holds great significance for driving our economic growth. Integrating decision-making related to resource allocation and use, spatial and temporal mapping mechanisms, research initiatives, and environmental monitoring is crucial to implement blue economy strategies successfully. Considering the diverse range of natural and human-induced activities in the marine environment, efficient information flow and inter-agency coordination are paramount. Key tools such as marine spatial planning and integrated coastal management can be leveraged to comprehend the complexities of coastal and marine areas and propel the nation into a higher growth trajectory. This paper attempts to assess India's existing and emerging maritime sectors and their alignment with the United Nations Sustainable Development Goals. It aims to provide a comprehensive list of these sectors while highlighting their significant contributions and impact on the three pillars of sustainable development: economic, social, and environmental. The course of action for attaining blue economy targets should be so planned that the economic benefits are balanced with sustainability. As a nation, India can take immediate actions to jointly move ahead

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towards the path of blue economy, 2021-30 being proclaimed the Decade of Ocean Science for Sustainable Development by the United Nations. This study is expected to interest researchers and practitioners working across the coastal and marine domains.

Keywords: Blue Economy, Maritime Sectors, Oceans, Sustainable Development Goals, Economic Growth

Enabling shrimp farming through Remote Sensing AI

[ABS-12-0324]

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Captain Fresh

Shrimp farming plays a pivotal role in India's blue economy, serving as a major economic activity and positioning the country as a leading exporter of shrimp worldwide. However, this sector faces numerous risks and uncertainties, including volatile markets, climate variability, and production-related challenges. Moreover, unregulated shrimp farming practices can pose a significant threat to water bodies, potentially causing pollution and systemic risks to local ecosystems. To address these risks and promote sustainable practices, farmers must adopt effective risk management strategies and make informed decisions regarding cultivation intensity, evaluating farming practices and their confidence in managing risk. Notionally, aquaculture research has overlooked these critical factors This abstract proposes a modular framework using data-driven decision-making to mitigate risks in shrimp farming. The framework leverages satellite imagery analysis, AI/ML methodologies, and digitization tools for farm operations to establish end-to-end traceability in the shrimp farming ecosystem. The proposed approach holds great potential for optimizing returns on investment for producers, procurement companies, and processors, while upholding sustainability and traceability metrics. Our framework integrates farm operations data with remotely sensed spatio-temporal data to accurately predict pond boundaries. These boundaries are crucial for analyzing cultivation cycles. We have developed a Deep Learning based pond boundary detection model by fine-tuning Meta's Segment Anything Model with custom-labeled data from coastal Andhra Pradesh and Tamil Nadu. The model achieved a mean Intersection over union (IoU) of 0.93, demonstrating impressive performance. The paper examines analytical inferences from detected pond boundaries, including identifying intensive/extensive cultivation, aiding risk hedging for procurement companies, estimating harvest readiness for planning supply potential, developing spectral/SAR indices for growth stages in shrimp farming and monitoring water quality parameters to raise production risk alerts. Implementing this framework

benefits major stakeholders in the industry, including large-scale farmers, procurement companies, exporters, insurance providers, and government agencies. It enables monitoring of shrimp farms, mapping high-quality and traceable shrimps, assessing risks for insurance, and ensuring sustainability and ecological safety. In conclusion, our modular framework fosters sustainable development in shrimp aquaculture, elevating the sector and delivering economic prosperity, environmental sustainability, and enhanced traceability.

Keywords: Traceability, CNN, Sustainability, Semantic Segmentation, SAR, Remote Sensing

Primary productivity for sustainable marine fishery resources: A precursor for blue economy

[ABS-12-0478]

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Indian National Centre for Ocean Information Services

The sustainable use of marine natural resources is critical for Blue Economy. India has over 8000 km of coastline with an enormous potential for marine fishery resources. Several people living along the coastline primarily depend on fishery resources for their livelihood. Identifying the appropriate fishery resources in the sea is always a difficult task with a lot of human efforts and burning fossil fuels. The Indian National Centre for Ocean Information Services (INCOIS) provides advisories on the potential fishing zone (PFZ) that helps fishermen to locate fish aggregation, thereby reducing the search time and less burning of fossil fuels. Thus, these advisories are meant to improve profitability and socio-economic status. Presently the advisories are based on the satellite-retrieved sea surface temperature and chlorophyll-a, which is considered to be the index of primary productivity. With the recent advancement of satellite technology and novel bio-optical algorithms, it is possible to retrieve primary productivity from satellites directly. Therefore, generating PFZ advisories directly from satellite-based primary productivity will provide a significant reduction in data processing. In this study, the climatology of the PFZ lines were generated at a seasonal scale using 10 years of data. Further, the variability of five primary productivity models (VGPM, Eppley-VGPM, CbPM, CAFE and SABPM) were evaluated across PFZ lines in off Kochi and Visakhapatnam. The frequency-density distribution of PFZ lines revealed the highest concentration in the shelf region along the 200m bathymetry with significant variability at the seasonal scale. Further, the comparison with in-situ data indicates better performance of the CbPM model with a correlation of 77% and an estimated error of 38%. Moreover, it was observed that the primary productivity was higher in nearshore waters, gradually decreasing further offshore towards the PFZ lines. In the Visakhapatnam area, the CAFE estimation exhibited a negative correlation in all seasons except JJAS, where Eppley-VGPM showed a strong correlation. The study is a precursor for providing primary productivity-based fishery advisory for proper harvesting, thus boosting the blue economy.

Keywords: Fishery, Primary Productivity, Model, Satellite, Algorithm

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Sub-Theme-13

Marine Resource Management

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Reg. ID	Abstract Title	First Author
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ABS-13-0239	Species sensitivity distribution of anthracene toxicity on marine organisms for the development of seawater quality criteria	Karthikeyan P
ABS-13-0241	Sea Water Quality Criteria for arsenic, cadmium and lead through Species Sensitivity Distribution	Marigoudar S R
ABS-13-0406	Large-scale seaweed cultivation in Indian coastal regions; a primer on regional bio-security concerns	Renjith Vishnu Radhan
ABS-13-0202	Amalgamating acoustic and in situ measurements for evaluating zooplankton biomass in the Eastern Arabian Sea with ADCP integration	Shirin Jayvant Jadhav
ABS-13-0243	Effects of Cd & Pb on plankton population and community structure - a mesocosm study	Raja P
ABS-13-0474	Bleaching of zoanthus (Palythoa sp.) colonies at Thikkodi rocky reef ecosystem ¿ a signal of warming of coastal waters along Kerala Coast	Amjad Hakim

Spatial patterns and variations of deep scattering layers in the Arabian Sea - A baseline study

[ABS-13-0130]

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Mesopelagic communities play an important role in the transfer of energy in the open-ocean food webs and are key prey group for many higher predators. So, the investigation of mesopelagic organisms, specifically micro-nektons, and their formation of deep scattering layers (DSL) is of significant interest. DSLs are extensively distributed in all oceans, especially in tropical waters. In this study, we aimed to explore the spatial variations of DSL and potential migration patterns by examining the DSL between the time interval of 5:45 to 12:00hrs and 16:00 to 20:00hrs for studying their ascending and descending migration using the Echosounder (EK60) onboard the research vessel Sagar Sampada. Based on the Cluster analysis applied in the data, the study area is divided into two regions, North Eastern Arabian Sea (NEAS) (16°N to 22°N, 66°E to 69°8E) and South Eastern Arabian Sea (SEAS) (8°N to 15°N, 65°E to 76.3°E). The extend of diel vertical migration varies for NEAS and SEAS, and recorded as S-150m (200-470m) & S-150m (300-600) respectively during night (day). The analysis shows that the characteristics of the DSL exhibited substantial variations along the latitudinal gradient. Notably, the proposition of migration DSL thickness was more pronounced in the SEAS region compared to the NEAS region. The group and species assemblages from north to south are closely linked with DO levels in the intermediate water depths and water density. The group assemblage and diversity are high in SEAS compared to NEAS while the biomass is high in NEAS (11 m tonnes, 9 m tonnes (SEAS)). In NEAS the biomass are contributed by a single or a few dominating groups or species (Benthosema fibulam 30%, Diaphus arabicus 22% & Bolinicthys longipes 20%) while in SEAS(B. fibulatum 19%, D. thriolleri 17%, Myctophum spinosum 13%, D. garmani 9%, B. pterotum 9% , Bolinicthys longipes 9%, D. arabicus 9%) we can see an equal contribution of group to its biomass. This study provides baseline information on the mesopelagic communities and their habitat distribution within the DSL of the Arabian Sea, utilizing trawl data and supported with the acoustic profiles collected on-board FORV Sagar Sampada.

Keywords: Deep Scattering Layer, Arabian Sea, OMZ, DO, NEAS, SEAS

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Species sensitivity distribution of anthracene toxicity on marine organisms for the development of seawater quality criteria

[ABS-13-0239]

Karthikeyan P*, S. R. Marigoudar, P. Raja, A. Nagarjuna, S. Barath Kumar, M. Savurirajan, K.V.Sharma
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Anthracene (ANT) is a priority polycyclic aromatic hydrocarbon found in seawater from anthropogenic activities and is toxic to marine organisms. Acute and chronic toxicity values were determined for ANT from the bioassays on five species of endemic marine organisms from diatom (T. subtilis and E. paludosa), copepod (O. similis and T. furcata) and shrimp (L. vannamei). Post larvae of shrimp were found to be most sensitive to ANT toxicity. Acute toxicity values, 96h-EC50 (Median Effective Concentration) and 96h-LC50 (Median Lethal Concentration) ranged between 23.98±2.4 µg/l and 1.73±0.33 mg/l. Chronic toxicity values such as NOEC (No Observed Effect Concentration), LOEC (Lowest Observed Effect Concentration), and chronic values ranged from 2.1±0.6 µg/l to 267±58 µg/l, 2.5±0.8 µg/l to 400±7 µg/l and 2.4±0.8 µg/l to 327±71 µg/l respectively. Seawater quality criteria viz. PNEC, CCC, and CMC were derived using NOECs, chronic values, and acute data from this study with the values matching that reported in literature. The PNECs are pertinent to sensitive/protected waters, CCC can be applied across the coastal waters and CMC for accidental spill/outfalls/discharge points in enclosed waters. These criteria are derived using the species sensitivity distribution methods by Australian Burrlioz and USEPA (United States Environmental Protection Agency). The PNEC, CCC, and CMC are derived as 2.7, 8.8, and 17 µg/l respectively from the Australian Burrlioz SSD whereas the USEPA SSD resulted in 3.89 µg/l of PNEC, 10.7 µg/l of CCC, and 26.7 µg/l of CMC. Australian Burrlioz SSD provides slightly more stringent criteria than USEPA SSD. The criteria serve as a reference value for establishing enforceable water quality standards appropriate to designated use classes of coastal waters for the protection of marine life across India and beyond as well.

Keywords: Seawater Quality Criteria, Anthracene, Pahs, Species Sensitivity Distribution, Acute And Chronic Toxicity

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Sea water quality criteria for Arsenic, Cadmium and Lead through species sensitivity distribution

[ABS-13-0241]

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Coastal water pollution by metals from human activities is greater environmental concern in India. Water quality standards are playing vital role in the regulation of aquatic pollution. Seawater quality criteria (SWQC) for arsenic (As), cadmium (Cd) and lead (Pb) are developed based on species sensitivity distribution (SSD). Acute and chronic toxicity data for As, Cd and Pb on eight species of endemic sensitive marine organisms belonging from five phyla were derived through toxicity bioassays. Median effective concentrations (EC50) and median lethal concentrations (LC50) were derived from the acute toxicity bioassays. No Observed Effect Concentrations (NOEC), Lowest Observed Effect Concentrations (LOEC) and chronic values were derived from chronic toxicity bioassays. Diatoms were more sensitive to As with 96h EC50 of 0.1 mg/l and copepods were more sensitive to Cd and Pb with 96h EC50 of 0.019 mg/l and 0.05 mg/l. NOECs ranged from 4.87 to 21.55 µg/l of As, 1.0 to 120 µg/l of Cd and 5.67 to 91.67 µg/l of Pb. Similarly, chronic values distributed in the range of 6.71-26.1 µg/l, 1.38-170 µg/l, and 7.67 to 91.67 µg/l of As, Cd and Pb. The Criterion Maximum Concentration (CMC), Criterion Continuous Concentration (CCC) and Predicted No Effect Concentration (PNEC) values were prescribed as SWQC. The CMC of 33.79 µg/l, 4.87 µg/l and 26.95 µg/l for As, Cd and Pb respectively are derived for acute exposure during accidental and sudden outfalls. The CCC of 4.99 µg/l of As, 1.32 µg/l of Cd and 4.32 µg/l of Pb recommended as WQC for protecting 95% of marine organisms from metal toxicity. PNEC of 3.05 µg/l of As, 0.74 µg/l of Cd and 2.65 µg/l of Pb suggested for highly disturbed ecosystems, shell fishing and mariculture uses of water bodies. These values may also serve as a baseline for site specific water quality criteria in the country.

Keywords: SSD, Metals, Toxicity, Sea Water Quality, Pollution

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Large-scale seaweed cultivation in Indian coastal regions: A primer on regional bio-security concerns

[ABS-13-0406]

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Biosecurity is a comprehensive concept that encompasses strategic policy and regulatory frameworks aimed at analysing and managing risks in areas such as food safety, public health, and the well-being of animal and plant life. It also addresses associated environmental risks. Seaweed farming, while offering potential benefits such as addressing climate change and global hunger, presents biosecurity-related risks, including those pertaining to the environment, production, and economics. The Government of India recognizes the potential of seaweed cultivation and has actively promoted its culture, targeting a production of over 11.2 lakh tonnes by 2025, considering it as a future crop for the country. Consequently, there has been a surge in the establishment of seaweed farms along India's coastal regions. However, there exists a knowledge disparity regarding the potential consequences of large-scale farming practices. Seaweed agriculture, despite its numerous favourable prospects, poses unique risks that are often overlooked. These risks include genetic pollution, nutrient depletion, diseases, the introduction of invasive species, changes in ambient organic carbon levels, and the creation of artificial habitats. Furthermore, external factors such as cyclones, given the year-round cyclone season in the Indian Ocean region and the increasing intensity of severe cyclonic storms in the North Indian Ocean region, can adversely impact these farms. All these factors interact dynamically with the prevailing socioeconomic conditions of the aquaculture regions. In the context of seaweed cultivation and its associated socioeconomic systems, a temporal perspective reveals similarities to complex adaptive systems. Consequently, we aim to decipher the interactions and feedback mechanisms within this system resulting from large-scale seaweed cultivation, particularly with regard to Indian coastal waters. To achieve this, we employ a system dynamics approach. Furthermore, we propose region-specific considerations, including the promotion of indigenous species, and emphasize the importance of developing best farming practices that account for the regional carrying capacity of coastal waters.

Keywords: Seaweed, Biosecurity, Marine Environment, Aquaculture

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Amalgamating acoustic and *in situ* measurements for evaluating zooplankton biomass in the Eastern Arabian Sea with ADCP integration

[ABS-13-0202]

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Enumerating the plankton and other living organisms are critical towards the understanding of the habitat and the ecological interactions that ultimately are critical input to evaluate the ecosystems and its resources. One of the emerging techniques for the zooplankton biomass estimation is the use of acoustic based instruments/methods through various approaches. Present study explains an attempt that employ a suit of acoustic and in-situ measurements to evaluate the mixed layer zooplankton biomass with Acoustic Doppler Current Profiler (ADCP) integration. The area selected for the study is South Eastern Arabian Sea (SEAS) during May-June and Sept-Oct 2005 on-board the FORV Sagar Sampada. The study employed in situ measurements of vertical zooplankton using Multiplankton Net (MPN), as well as acoustic estimation of zooplankton biomass utilizing the backscatter strength [Sv dB re (4πm)-1] obtained from the Vessel Mounted Broad Band ADCP operating at a frequency of 75 KHz. The backscatter intensity was determined using the operational form of the sonar equation. Data on echo intensity from RDI's VMBB ADCP and MPN collections were made at selected stations in the area 8°-21°N to 68°-76.6°E. Regression equations giving the proxy of zooplankton biomass were derived separately for the May-June and Sept-Oct periods using 39 and 58 samples, respectively. The estimation was restricted to the water column up to the mixed layer depth, excluding the upper layer's ringing distance, also taken care to filter the Received Signal Strength Indicator (RSSI) to avoid the influence due to larger DSL organisms like myctophids. ADCP transects and net tows were utilized to capture signals from vertically migrating organisms. The sampling stations were distributed along eight transects at latitudes 8°N, 10°N, 11.5°N, 13°N, 15°N, 17°N, 19°N, and 21°N. Comparing the acoustic technique-based estimates of zooplankton biomass with conventional techniques, a closer agreement was observed for the May-June period (correlation coefficient R = 0.58), while a weaker correlation was found for the Sept-Oct period (R=0.25). In addition, the study highlights the connection between areas exhibiting significant acoustic backscattering and surface characteristics indicative of a productive environment.

Keywords: Acoustic Doppler Current Profiler, Zooplankton Biomass, Ecological Interactions

Effects of Cd & Pb on plankton population and community structure - a mesocosm study

[ABS-13-0243]

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Metals are toxic to the aquatic ecosystem at elevated levels. Higher metal concentration alters the ecosystem in terms of food chain shifts in the plankton community. Impact of Cd and Pb at threshold concentrations on plankton population and community structure was studied by a short-term open sea mesocosm experiment at Vishakhapatnam coastal waters. Threshold concentrations of Cd (PNEC-0.6 µg/l, CCC-3.0 µg/l and CMC-23 µg/l) and Pb (PNEC-2.7 µg/l CCC-4.5 µg/l and CMC-130 µg/l) was used for experiment. High nutrient concentrations and phytoplankton biomass (Chl-a <8.64 mg/l) observed in the mesocosm bags and did not show a significant difference in phytoplankton community structure. The plankton population and community structure are significantly differed from the control at all the threshold levels of metals. A high abundance of diatoms was observed up to 48 hrs in the PNEC, CCC & CMC concentrations, whereas the diatom population was decreased after 72 hrs. Chaetoceros sp. was dominant in the control bag, Prorocentrum sp. Ceratium sp. Tintinopsis sp. Chaetoceros sp. and Skeletonema sp. were abundant in the mesocosm bags with the metal concentrations at PNEC, CCC & CMC levels. Analysis of PCA and hierarchical cluster confirmed that increasing metal concentration in enclosed system altering phytoplankton species shift in CCC & CMC systems. Induced catalase production (5.99 nmol/min/ml) showed the plankton responded to eliminate the metal concentration. The results are confirmed that short-term exposure to threshold metal concentration affects the phytoplankton community in terms of alteration in species diversity and abundance. The insights from this study will serve as the baseline information for ocean modelling studies and help in environmental management tools to mitigate metal pollution. Further long-term mesocosm experiments are needed to observe the metal detoxification mechanisms at the cellular level in a detailed manner and the metal transfer rate at higher trophic levels.

Keywords: Mesocosm, Metals, Threshold Levels, Plankton Community Structure, Enzyme Activity

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Bleaching of Zoanthus (Palythoa sp.) colonies at Thikkodi rocky reef ecosystem - a signal of warming of coastal waters along Kerala Coast

[ABS-13-0474]

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Bleaching of corals and other cnidarians are more frequent and severe in recent years as climate changes. Loss of symbiotic algae (Zooxanthellae) from cnidarians leads to the bleaching in large scale due to environmental stress, especially elevated temperatures in coastal waters. In this study, observations on bleaching were recorded in the colonies of green aggregating zoanthids (Palythoa sp.) from the rocky reefs of Thikkodi, south west coast of India during the post and pre monsoon 2022-2023. Palythoa sp. which belongs to the Phylum Cnidaria, Class Anthozoa and are abundant in the rocky reefs of the study area. Palythoa sp. harbours the symbiotic algae, the Zooxanthellae which possesses chlorophyll and release oxygen as a by-product of photosynthesis. Visible loss of colour among zooxanthellate cnidarian colonies indicates a stress-induced decline of endosymbiotic algae. Bleaching is driven by many factors, chief among them is the increasing sea surface temperatures associated with ongoing climate change. Mass bleaching events of Palythoa sp. have been observed in almost all subtropical and tropical reef areas. In the rocky reef ecosystem of Thikkodi, mass bleaching events were recorded during the pre-monsoon period (May 2023) and no bleaching was observed during post mnsoon (December 2022). The zoantharian Palythoa sp. bleaches earlier than many scleractinian corals and may serve as an indicator species. So, Palythoa sp., can be highlighted as a good indicator of coral or cnidarians bleaching because it is highly susceptible to bleaching under physiological stresses, especially elevated water temperatures and it is usually one of the first species to show symptoms. Direct detection of such bleaching events on local scales has become a key component of monitoring of ecosystem health. Although satellite-based observations have greatly improved our capacity to anticipate bleaching events, the data are not readily available in certain coastal areas,

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and local variability may necessitate targeted observation. Basic monitoring of such species could help to detect and even anticipate bleaching events, especially in areas where more sophisticated approaches that rely on buoy or satellite measurements of sea surface temperature are unavailable or too untraceable.

Keywords: Zoanthus, Bleaching, Warming, Kerala Coast, Reef Monitoring

Sub-Theme-14

IMS Special Session on Importance of Ocean Observations to Monsoon Weather and Climate Forecasting

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Association between the meridional displacement of the Asian jet and Indian summer rainfall in CMIP6 models impact of El Nino and PDO

[ABS-14-0200]

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Influence of meridional displacement of the Asian jet on the Indian summer monsoon (ISM) rainfall in CMIP6 models historical runs is examined for the period of 1901 to 2015. The leading mode of variability in the upper-tropospheric zonal wind anomalies along the Asian jet exhibits a north¿south seesaw pattern on the interannual time scale in on the observations and CMIP6 models. The strength of the meridional displacement the summer Asian jet is stronger over the East Asian region in most of CMIP6 models unlike in the observations. The southward displacement of the Asian jet (SWDAJ) provoke reduced precipitation over the central and northern India region in observations and CMIP6 models. However, relation between ISM rainfall and SWDAJ is over estimated in some models. We have classified models into three categories and used three groups of Multi-model mean. In the first group the top 5 models in which SWDAJ and ISM relationship is over estimated or highly correlated (MMM-H), the models in which correlation is close to the observations (MMM-C) are in second group and in third group, correlation between SWDAJ and models is underestimated or low correlation (MMM-L). It is found that strength of SWDAJ is strong in MMM-H compared to other groups. Further analysis suggests that meridional displacement of Asian jet is strongly influenced by the Pacific Decadal Oscillation (PDO) and El Nino. Mechanisms responsible for changes in Asian jet due to PDO/El Nino are further examined.

Keywords: Asian Jet, Pacific Decade Oscillation , El Nino, Summer Monsoon, Coupled models

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Reception, monitoring and assimilation of Ocean observations for NWP at NCMRWF

[ABS-14-0176]

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NCMRWF receives global ocean in-situ observations from BUOY (moored and drifters), SHIP, and ARGO through the Global Telecommunication System (GTS) via the India Meteorological Department (IMD) from the Regional Telecommunication Hub (RTH) New Delhi. The BUOY observations over the North Indian Ocean (NIO) operated by INCOIS/NIOT and other international agencies are also received regularly at NCMRWF through the GTS. NCMRWF shares the processed BUOY, SHIP, and ARGO observations with INCOIS for the generation of Ocean analysis. NCMRWF routinely monitors all the Ocean observations being received through GTS. This study focuses on the reception, monitoring, quality control and assimilation of global BUOY observations (Surface pressure, atmospheric temperature, sea surface temperature, humidity and wind) with particular emphasis over the NIO. Special emphasis is given to the analysis of spatio-temporal variation of BUOY observations during the NIO cyclone season. The impact of BUOY observations in the NCMRWF Analysis and forecast system has also been investigated during two cyclones, ¿Gulab¿ formed over the Bay of Bengal crossed the Indian land mass and caused the genesis of another cyclone ¿Shaheen¿ from its remnants over the Arabian sea during the late south west monsoon season of 2021 (September).

Keywords: North Indian Ocean, BUOY observations, Tropical cyclones

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Observation-driven insights into monsoon dynamics: A pathway to improved understanding of 2018 South West Monsoon Onset

[ABS-14-0114]

Vaibhav Tyagi*, Sambit Kumar Panda, Bipasha Paul Shukla, Saurabh Das, Abhisek Chakraborty, Atul Kumar Varma
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The Indian monsoon is a complex phenomenon that greatly impacts agriculture and the economy of the region. Accurate prediction and understanding of the monsoon onset are essential for effective planning and management. This study analyses various parameters, including scatterometer sea surface winds, outgoing longwave radiation (OLR), sea surface temperature (SST), and Doppler Weather Radar (DWR) reflectivity and velocity time series, during the onset (May 29, as per IMD) of the 2018 southwest monsoon. Sea surface winds from scatterometers, like SCATSAT-1 and the recently launched EOS06 (SCAT) by ISRO, provide valuable information on wind speed and direction, enabling researchers to monitor and predict monsoon patterns more effectively. The 5-day average (pentad) evolution of SCATSAT-1 winds reveals the consistent and substantial reversal in wind direction over the western Arabian Sea prior to the monsoon onset. This reversal was accompanied by a significant increase in cross-equatorial winds of about 15 m/s during the 16¿20 May pentad. This change in wind patterns indicates the approaching monsoon and its influence on atmospheric circulation. Moreover, the pentad evolution of SST revealed an evident pre-monsoon increase starting on May 21, aiding in identifying warm oceanic regions as moisture sources for the monsoon. The study also analysed the time series of INSAT-3D derived OLR that revealed a significant decrease in OLR values below 180 w/m^2 from May 25 to May 28 in the region confined by 5 ¿10 degrees N and 70 ¿75 degrees E, indicating the development of active convection associated with the monsoon onset corroborated by infrared imagery from INSAT-3D, which revealed the presence of convective clouds during that time. Furthermore, radar reflectivity and velocity time series from the DWR after the monsoon onset were analysed, providing valuable information about the spatiotemporal evolution of precipitation systems associated

with the monsoon. By understanding the dynamics of these parameters during the monsoon onset, this study contributes to improving the accuracy of monsoon onset predictions. Our future plan is to catalyze our understanding with the data from newly launched EOS06 scatterometer for developing better frameworks for predicting the monsoonal dynamics.

Keywords: Southwest Monsoon, Onset, Scatterometer Winds, SCATSAT-1, OLR, SST, DWR

Delineation of most-favourable winds for South-West Monsoon Rainfall along Kerala coast

[ABS-14-0087]

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The most dominant region that encounters the southwesterly winds is the western coastal region of India. These winds bring about 80% of rainfall over India during June to September (southwest monsoon period). It can be justifiably presumed that faster winds are associated with more moisture as the winds bring moisture. Delineation of such favourable winds could make valuable inputs to prognostic models. During each month of the southwest monsoon and that during the pre- and post-monsoon, the daily winds are examined for the southwestern coast of India-Kerala. A higher precipitation occurs at the wind speed of 4-5 m/s during the monsoon months and at slower/weaker winds are found during the pre- and post-monsoon months. In comparison to that in Northern Kerala (4-5 m/s), these favourable winds are faster (5-6 m/s & 6-7 m/s) in Southern Kerala. The favourable winds over the offshore/seaward side are stronger than those over the coastal areas. It is noted that the precipitation is higher in the northern region than in the southern region. Wind direction associated with higher precipitation is East-Northeast in Northern Kerala and East in Southern Kerala. The winds and precipitation shows a correlation which is higher in the northern regions than in the southern regions. This indicates that higher prognostic value of the wind for monsoon forecast in Northern Kerala. All along the coast, the Principal Component Analysis of bi-plots of precipitation shows variability profiles of winds in the different class intervals. In general, the class-intervals of winds that comprise Principal Component-1 are not associated with the winds that induce higher precipitation, while the winds that are most favourable show lower variability indicated by proximity to Principal Component-2. K-Means Clustering indicates that the precipitation is found to be homogeneous in Southern Kerala in comparison to that in Northern Kerala.

Keywords: South West Indian Monsoon, Kerala Coast, Most-Favourable Winds, Principal Component Analysis, K-Means Clustering

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An inter-comparison of algorithms for detection and tracking of the north Indian Ocean tropical cyclones and their future projection

[ABS-14-0357]

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In the context of the availability of reliable model forecasts of high resolution, estimating the tropical cyclone tracks and intensity is key to save human lives and property. Various algorithms have been developed in the recent past by different research groups for tropical cyclones detection and tracking. This study aims to compare different tracking algorithms and formulations in detail to estimate the best algorithm. The performance of algorithms is examined by tracking cyclones with the help of European Centre for Medium Range Weather Forecast (ECMWF) reanalysis version 5 (ERA5) and ¿IMD best track data¿. The algorithms are developed based on widely used criteria. Detection rates, false alarm rate etc. are calculated for each tracking algorithm. Also, this study projects the tracks and intensity of tropical cyclones for the next three decades using high resolution Coupled Model Inter-comparison Project Phase 6 (CMIP6) historical simulations and projections. From the analysis, it is found that, detection rate and false alarm rates vary among the trackers. For best result it is suggested to use as many trackers as possible and average the results. After the analysis of trackers, projections of the track and intensity are made using the high resolution CMIP6 projections.

Keywords: Tracking Algorithm, Projection, CMIP6, False Alarm Rate (FAR) , Detection Rate

Interaction of multiscale weather events during the Indian Summer Monsoon and associated variability in the Ocean-Atmosphere coupled system: A study using ocean observations

[ABS-14-0501]

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The study focuses on the variability of Indian Summer Monsoon Rainfall (ISMR) based on the interaction of synoptic and several intraseasonal weather phenomena during the season. The intraseasonal weather events are usually represented by different indices which had a significant similarity despite their differences in formulation techniques. Madden Julian Oscillation (MJO) is one of such important atmospheric intraseasonal oscillations that impacts the Indian Monsoon in various aspects, which is majorly represented by all-season Realtime Multivariate MJO index (RMM). A similar northward propagation of rainbands during Indian Summer Monsoon (ISM) is known as Monsoon Intraseasonal Oscillation (MISO) and represented by MISO index. It was found that the cooccurrence of three typical phases of Madden Julian Oscillation (Phases 1,2, and 3) and Monsoon Intraseasonal Oscillation (Phases 6,7, and 8) causes a boost in moisture availability over equatorial Indian Ocean and the South Indian peninsula followed by increased rainfall. Monsoon Depression (MD) is another major contributor (45-55 %) of total rainfall during the season. The extended analysis also showed that 60 % of MDs occurred during the third and fourth phases of MISO. In understanding the role of ocean during the interaction of multiscale monsoonal activities, the climatological composite of Sea Surface Temperature (SST) was also analyzed. The result confirmed that, the spatial distribution of precipitation over the Bay of Bengal (BoB) does not match precisely with the climatological composite of SST for different phases of the MISO. Instead, the oscillation is evident within a confined area near the eastern coast and north of 15° N. The impact of SST with a lag of 6 to 12 days is significant in the central and western regions of the BoB. In addition to the satellite datasets, the in-situ data from ocean observation platform

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like OMNI buoys helped in unfolding the intraseasonal variability of both sub-surface and atmospheric parameters during the season. Surface salinity exhibits a negative intraseasonal signal during weak phases of MISO (7, 8, and 1), with a slight lag of 10-15 days due to freshwater influx from previous wet periods. Conversely, active phases (3 to 6) show a positive salinity signal due to delayed impact of increased evaporation. In corresponding years (2017 and 2018), consecutive repetition of phases 4 to 6, coupled with rising ocean heat content, is observed. Surprisingly, the intraseasonal variability of subsurface temperature was found to be higher during 2018, which was also corresponded with stronger signals of air temperature, sea level pressure and wind speed, aided a stronger MISO variability and formation of higher number of MDs in the respective year. The entire study acknowledges the extended and accessible ocean information which helps to understand and predict the role of ocean beforehand for ensuring a sustainable socioeconomic condition near the coastal ocean and over the Indian landmass.

Keywords: Keywords: Monsoon Intraseasonal Oscillation (MISO), Monsoon Depression, Subsurface Variability, Indian Summer Monsoon (ISM), Madden Julian Oscillation (MJO), OMNI Buoys

Can we predict Indian Monsoon Rainfall years ahead?

[ABS-14-0458]

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The importance of decadal prediction of monsoon, its societal impacts, and previously reported predictability of global precipitation based on coupled simulations, motivated us to explore the predictability of Indian Summer Monsoon Rainfall (ISMR). This study examines the decadal predictability of ISMR and the associated dynamical and thermodynamic variables affecting monsoon precipitation using Coupled Model Intercomparison Project Phase 6 (CMIP6) Decadal Climate Prediction Project (DCPP) hindcasts in a set of 10 years initialized each year from 1960-2019. The analysis is carried out for the Lead Year 1 (LY1), and by averaging 2-5 and 6-10 (LY2-5 and LY6-10) in the 8 CMIP6 model decadal hindcasts. It is noted that the skill of ISMR in the individual models and the multi-model mean is not satisfactory with respect to observed precipitation and is true for all the leads. However, significant skill is reported for tropospheric temperature (TT) averaged over the 600-200 hPa levels over the ISM region and Sea Surface Temperature (SST) across most of the global ocean. Notably, the SST skill is prominent over the Indian Ocean, West Pacific, and Atlantic regions, especially during LY 2-5 and LY6-10, however, correlation in the tropical eastern Pacific and southern Pacific are not significant. The TT predictability skill of models is highly significant for all leads but highest during LY2-5. Rainfall is extracted using model TT and SST considering the skills of models in capturing these variables over the key regions which affect monsoon. For this purpose, a multivariate linear regression model is developed based on model TT and SST to predict ISMR for different lead years. We have considered the TT averaged over the 30-90°E and 20-40°N regions, as well as SST averaged over the 125-150°E and 25-45°N regions for the regression model. By incorporating the multimodel mean TT and SST data, the model demonstrated improved precipitation skills for LY-1, LY2-5, and LY6-10. Enhanced air-sea interaction over the warmer Indian Ocean (IO) and the western Pacific contributed to the improved TT skill in the decadal hindcasts. Additionally, the role of both internal variability and external forcings on the significant SST skill is also examined.

Keywords: Indian Summer Monsoon Rainfall, Sea Surface Temperature, Tropospheric Temperature

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Impact of LETKF-based coupled data assimilation on seasonal prediction of Indian Summer Monsoon

[ABS-14-0257]

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This study investigates the effectiveness of advanced Data Assimilation (DA) methods in improving seasonal predictions of the Indian Summer Monsoon (ISM) by examining two extreme event cases. The coupled reanalysis products, namely the Indian Institute of Tropical Meteorology, University of Maryland-Weakly Coupled Analysis (IWCA), and the Climate Forecast System Reanalysis (CFSR), and the uncoupled reanalysis products from NCMRWF-GFS and INCOIS-GODAS. Given the increasing frequency and severity of droughts and floods, accurately predicting extreme events is crucial for effective preparedness and mitigation. The IWCA implements the local ensemble transform Kalman filter, incorporating theoretically advanced flow-dependency features and ensemble-based analysis compared to CFSR. The CFS version-2 predictions using IWCA simulate the large-scale monsoon features and convection centers well and improved prediction skill (~22%) compared to CFSR predictions, with a gain of one month lead time. The enhanced analysis quality and cross-domain equilibrium in IWCA reduce initial shocks in springtime predictions. Further, the sustained ensemble consistency aided in simulating the variability better and improved the seasonal forecasts. The study strongly advocates adopting advanced CDA methods for seasonal monsoons and probable seamless predictions. Hindcasts using coupled and uncoupled Initial Conditions (ICs) from the CFSv2 model are generated to assess their respective predictive capabilities for extreme events. Notably, the IWCA forecast captured consecutive years of Indian monsoon droughts, excess rainfall events, and associated atmospheric and oceanic conditions. This demonstrates the enhanced forecasting ability provided by advanced DA methods in accurately predicting the ISM and facilitating better preparedness and mitigation measures for extreme events.

Keywords: Coupled Data Assimilation, Seasonal Prediction Of ISM, Extreme Event Prediction, LETKF Data Assimilation

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Impact of decadal variability of Cross Equatorial Cell on the Indian Ocean and its association with climate variability

[ABS-14-0340]

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The variability of Cross Equatorial Cell (CEC), which connects the North Indian Ocean circulation with the South Indian Ocean is studied using century long ocean reanalysis dataset. To quantify the strength of CEC, a CEC index is defined based on the strength of the detrended meridional overturning stream function estimated over the Indian Ocean and averaged between the latitudes 2oN and 2oS, where its standard deviation displayed maximum. The inter-consistency between the datasets in representing the CEC index during annual, summer (June, July, August, and September), fall (October to November), and winter (December, January, and February) is examined. Boreal fall displayed the maximum standard deviation of the CEC index, followed by summer. Also, the spectrum analysis of the CEC index during boreal fall was carried out to identify the dominant signals representing the variability of CEC transport. The bandpass filter was used to filter the signal at the decadal timescale for further analysis. The strong and weak CEC years are identified based on the standard deviation of the bandpass-filtered boreal fall CEC index. The spatial variation of decadal CEC is investigated during strong and weak years. The meridional heat transport associated with CEC was also examined. The impact of the decadal variability of CEC on the upper ocean thermal state of the North Indian Ocean. The correlation analysis of bandpass filtered CEC index with OHC anomaly, D20 anomaly, and Sea level anomaly was carried out. The results' consistency is confirmed based on observation-based analysis datasets during their respective available periods. To study the role of dominant climate variability driving the decadal CEC variability, 31 years of moving correlation analysis is carried out between the bandpass filtered CEC index and the climate indices. The analysis revealed that the Pacific Decadal Oscillation displays a significant relationship with CEC variability. Thus the study concludes that the CEC decadal variability during boreal fall is significant and is associated with Pacific Decadal Oscillation.

Keywords: Decadal Variability, Cross Equatorial Cell, Indian Ocean, Ocean Heat Content, Climate Variability

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Importance of long-term temperature and salinity observations in predicting weather and climate

[ABS-14-0395]

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The dynamic interaction between Earth's atmosphere and ocean surface plays a crucial role in shaping weather patterns and climate variability. The ocean's influence on weather and climate is primarily governed by processes occurring in a few tens meters of water column below the sea surface. Therefore, Ocean observations, particularly temperature and salinity measurements, are crucial in understanding and predicting weather and climate patterns. The oceans act as a vast heat reservoir, absorbing and distributing energy across the Earth's surface, making them a vital component of the global climate system. The in situ temperature measurements at different depths and locations help to identify oceanic features like currents, upwelling zones, and eddies, which influence atmospheric circulation and weather systems. Salinity, is equally essential in understanding the ocean's influence on weather and climate. Salinity affects the density and circulation of seawater, driving ocean currents and the global thermohaline circulation. These in situ data also provide initial conditions for model simulations and constrain the physical processes that occur in the atmosphere-ocean system. Improved accuracy in initial conditions and boundary conditions derived from ocean observations enhances the reliability of weather forecasts. Thus, ocean observations, particularly temperature and salinity measurements, are indispensable for predicting weather and climate patterns. They provide crucial information on the distribution of heat, moisture, and circulation patterns in the oceans, which have far-reaching impacts on atmospheric conditions and climate variability. Integrating these observations into numerical models enhances the accuracy of weather forecasts and improves our understanding of long-term climate trends. By investing in robust ocean observation systems, we can strengthen our ability to predict and respond to weather and climate-related challenges, ultimately contributing to the well-being and sustainability of our planet. This study explores the importance of ocean observations, specifically temperature and salinity, in enhancing weather and climate predictions.

Keywords: Temperature, Salinity, Ocean Observations, Weather, Climate

To cite abstracts in this volume

Author list, (2023), Title of the abstract, Eds. Francis P. A., P. Srinivas, R. S., Mahendra, N, Kiran Kumar, B. Praveen Kumar, P. Vijay, B. Rohith, OSICON-23, INCOIS, Hyderabad, ISBN: 978-81-923474-7-9, pp489.

Example:

Junaid C.K., V. Suneel, P. S. Karthika, (2023), Importance of long-term temperature and salinity observations in predicting weather and climate, Eds. Francis P. A., P. Srinivas, R. S., Mahendra, N, Kiran Kumar, B. Praveen Kumar, P. Vijay, B. Rohith, OSICON-23, INCOIS, Hyderabad, ISBN: 978-81-923474-7-9, pp489.

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978-81-923474-7-9